UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF WILLOW CREEK DAM AUXILIARY SPILLWAY

Hydraulic Laboratory Report No. Hyd-356

ENGINEERING LABORATORIES

OFFICE OF THE ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

June 8, 1954

FOREWORD

Hydraulic model studies of the Willow Creek Dam auxiliary spillway, a part of the Colorado-Big Thompson Project, were conducted in the laboratory of the Bureau of Reclamation at Denver, Colorado, during the period of August 1950 to May 1951.

The final plans evolved from this study were developed through the cooperation of the staffs of the Spillway and Outlet Works Design Section and the Hydraulic Laboratory.

During the course of the model studies, Messrs. H. W. Tabor, R. W. Whinnerah, J. C. Doman, and others of the Spillway and Outlet Works Design Section frequently visited the laboratory to observe the model tests and discuss the results.

These studies were conducted by G. L. Beichley with the aid of H. L. Blackman, under the direct supervision of W. E. Wagner, A. J. Peterka, and J. N. Bradley.

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Office of the Assistant Commissioner
and Chief Engineer
Engineering Laboratories
Denver, Colorado
June 8, 1954

Laboratory Report No. Hyd-356
Hydraulic Laboratory
Compiled by: G. L. Beichley
Reviewed by: A. J. Peterka

Subject: Hydraulic model studies of Willow Creek Dam auxiliary spillway

SUMMARY

Hydraulic model studies of Willow Creek Dam auxiliary spillway (Figures 1, 2, and 3) were made on a 1:15 scale model (Figures 4, 5, and 6) for the purpose of developing and checking the hydraulic design. Data and notes taken on the flow in the model showed the preliminary design of the U-shaped double-side channel spillway structure in general to be satisfactory. The width of the "U" and the crest length were sufficient to prevent crest submergence except for discharges greater than the design capacity. It was found, however, that the chute floor could be simplified for prototype construction by eliminating the step (Figures 5, 6, and 7) located just downstream from the double-side channel crest; and that the spillway chute should be extended approximately 100 feet farther downstream.

Flow through the preliminary chute (Figures 8 and 9) was satisfactory, but it was felt that the step in the chute floor was not beneficial in producing smooth flow. It was, therefore, eliminated in the recommended design (Figures 3 and 6).

Flow leaving the preliminary structure had a tendency to scour a deep hole near the end of the chute (Figures 16, 17, and 18), therefore, the chute was extended approximately 100 feet downstream. Thus, erosion which might occur near the end of the chute would not endanger the nearby access road (Figure 2). Attempts to "pitch" the flow downstream, away from the toe of the chute, by means of a deflector bucket were not successful because of the relatively low velocity of the flow. The performance of the recommended design is shown in Figures 15, 19, and 20.

Calibration of the model spillway (Figure 12) and pressure tests (Figure 13) showed the crest profile to be efficiently designed and without subatmospheric pressures. Water surface profiles were recorded in the downstream chute (Figures 21 and 22) to aid in determining the necessary training wall heights.

Flow conditions in the spillway approach (Figures 23, 24, and 25) were satisfactory. A minor disturbance at the left inlet wall (Figure 23) was not objectionable.

INTRODUCTION

Willow Creek Dam is a part of the Colorado-Big Thompson Project. It is located on Willow Creek near Granby, Colorado, Figure 1. The dam, Figure 2, is an earth-fill embankment approximately 1,050 feet long and 105 feet high above the river bed. The auxiliary spillway and a pump canal headworks is located on the left abutment, while the outlet works tunnel passes through the right abutment.

The auxiliary spillway, Figure 2, consists of a wide-spillway approach channel; a concrete U-shaped double-side channel crest structure; a concrete discharge chute; and a riprap-lined discharge channel extending downstream from the concrete chute. The concrete spillway structure is shown in Figure 3. It includes two inlet retaining walls and a bridge, as well as the double-side channel crest and chute. The spillway approach channel, Figure 2, is at elevation 8128 just 2 feet below the elevation of the weir crest. The weir crest is at elevation 8130 or 12 feet above the upstream end of the chute, and the upstream end of the chute is 25.22 feet higher than the downstream end. The chute floor width varies from 14 feet to 17 feet 4 inches and is 345 feet long measured horizontally.

The maximum design water surface elevation is just 2 feet above the crest at which elevation the spillway is designed to pass 3,100 second feet. Crest length is approximately 300 feet; therefore, the maximum design flow per unit foot of crest length is only approximately 10 second feet, but the flow per unit foot of chute width is approximately 200 second feet. The downstream 22.29 feet of chute consists of a 60-foot radius deflector bucket which directs the flow slightly upward and into the discharge channel. Flow from the discharge channel then spills out and over a mildly sloping hillside, re-entering Willow Creek at the foot of the hill.

THE MODEL

The model shown in Figures 4, 5, and 6 is a 1:15 scale reproduction of the auxiliary spillway and surrounding area. It was constructed and tested in the Bureau of Reclamation Hydraulic Laboratory at the Denver Federal Center.

Topography in the reservoir area was reproduced approximately 80 feet upstream from the U-shaped spillway, and approximately 90 feet to the right and 120 feet to the left of the spillway center line. Downstream from the end of the preliminary chute, the topography was reproduced for a distance of approximately 97 feet to the right and 82 feet to the left of the spillway center line.

Topography in the reservoir area of the model was molded of concrete mortar placed on metal lathe which had been nailed over wooden templates shaped to the profile of the ground surface. Model concrete surfaces simulating nonconcrete surfaces of the prototype, such as topography, were given a rough finish while concrete surfaces simulating prototype concrete surfaces were given a smooth finish. Topography in the downstream area was formed in 3/8-inch crushed rock in order to provide a movable bed in which to study the erosion characteristics of the flow leaving the structure.

The spillway crest, chute, and deflector bucket were molded in cement mortar. Sheet metal templates, accurately cut and placed, were used as guides. Piezometers over the spillway crest consisted of 1/16-inch inside-diameter copper tubes that were soldered at right angles to the profile of the template and filed flush.

Water was supplied to the model from the laboratory's permanent supply system. The discharge was measured by venturi meters. The reservoir elevation was measured with a hook gage in well located approximately as shown in Figure 4. The tail water elevation was to be uncontrolled and, therefore, no tail water elevation measuring device was needed. The tail water control gate shown in Figure 4 was provided for other purposes. Water surface elevations over the spillway crest and chute were measured with a sliding point gage mounted on rails as shown in Figure 5. Spillway crest pressures were measured using 10 piezometers on the spillway center line shown in Figure 4.

THE INVESTIGATION

The investigation was concerned with the over-all performance of the double-side channel spillway and with the erosion caused by the flow from the deflector at the end of the chute. The adequacy of the narrow U-shaped double-side channel crest structure in discharging the maximum design discharge of 3,100 second feet was of primary concern. This discharge corresponds to approximately 10 second feet per foot of crest length with a head of 2 feet on the crest; however, the discharge in the chute is approximately 200 second feet per foot of width. The investigation was also concerned with the spillway discharging greater amounts up to a maximum emergency discharge of 5,200 second feet which might occur if the spillway was required to discharge the outlet works flow of approximately 2,000 second feet in addition to the design flow of the spillway.

Lesser flows were also tested to be certain that the structure operated as intended and to study erosion patterns over the entire discharge range. The model study included the testing of the approach, the double-side channel crest, the crest profile, the chute, the deflector at the end of the chute, and the erosion caused by the flow leaving the chute.

Spillway Crest and Chute

Preliminary Design

Description. The preliminary design is shown in Figure 7. The U-shaped crest was approximately 300 feet long measured along the crest axis. The over-all length of the chute was 245.50 feet measured horizontally from Station 1+00. The over-all width of the structure varied from 38 feet 1-3/4 inches wide at Station 2+30, the downstream end of the U-shaped crest, to 31 feet 6 inches wide at Station 1+00, the upstream end. The chute floor was 15 feet wide from Station 1+00 to Station 2+40 and sloped downstream at the rate of 0.05 foot per foot of horizontal length. A crestlike step or rise in the floor at Station 2+40 was 3 feet 4 inches high. The chute floor width was 18 feet 4 inches wide downstream from the step and sloped downstream to the deflector at the rate of 0.0362-foot drop in 1 foot of horizontal length. The deflector at the end of the chute was a vertical curve in the chute floor that rose 3 feet in a horizontal distance of 9 feet 6 inches.

Flow characteristics. Flow approaching the structure appeared to be very satisfactory. Throughout the structure flow characteristics were very good for all discharges up to 4,400 second feet and were acceptable up to the maximum possible discharge of 5,200 second feet. The flow moved through the structure smoothly and without undue disturbance as shown in Figure 8 for the design discharge of 3,100 second feet and for 5,200 second feet.

For discharges less than 4,400 second feet, the flow entering the chute of the double-side channel spillway created a boil along the center line of the U-shaped structure as shown in Figure 9. The U-shaped structure was sufficient to discharge flows up to approximately 4,400 second feet before any part of the crest became submerged.

For discharges of 4,400 second feet and over, the boil could not be detected in the upstream portion of the structure because the crest in this vicinity was submerged as shown in Figure 9. For 5,200 second feet discharge, the water surface downstream from the U-shaped spillway above the step in the chute floor was rather rough and irregular. It was believed that the step in the chute floor was partly responsible for the rough water surface encountered.

Water surface profiles were recorded for 2,000, 3,100, and 5,200 second feet along the chute center line as shown in Figure 10. Transverse water surface profiles were also recorded at several stations along the center line as shown in Figure 11.

Calibration. Calibration of the spillway crest disclosed the capacity of the spillway for the design reservoir elevation to be 3,050 second feet as shown by the discharge curve in Figure 12 which is very close to the anticipated flow of 3,100 second feet. The efficiency of the crest was indicated by the coefficient of discharge "C" in the discharge equation:

$$Q = CLH^{3/2}$$

where

Q is the total discharge
L is the length of the crest line, and
H is the head of water on the crest

The coefficient of discharge is plotted against reservoir elevation in Figure 12 and indicates an efficient design. For the design reservoir elevation the coefficient is about 3.62 and even larger for lower reservoirs.

For emergency discharges of 4,400 second feet and above, the U-shaped spillway crest became partially submerged as indicated by the abrupt change in the direction of the discharge curve and by the rapid decrease in the value of the coefficient. For the maximum possible emergency flow of 5,200 second feet, the U-shaped crest became almost completely submerged and the reservoir rose to approximately elevation 8133.4.

Since the coefficient of discharge "C" was relatively high and since submergence of the crest did not increase excessively the reservoir elevation for high discharges, the spillway was considered to be satisfactory both in the arrangement of the "U-shape" and in the cross-sectional shape of the crest profile.

Pressures. Pressures on the spillway crest were checked at the upstream end on the center line of the spillway with the 10 piezometers shown in Figure 4. Pressures were recorded for discharges of 1,000, 2,000, 3,100, 4,000, and 5,200 second feet as shown in Figure 13. All pressures were near atmospheric or above. Except where the nappe was submerged, the nappe exerted only a very slight pressure, if any, on the crest profile; therefore, the crest was shaped as efficiently as possible without designing it for subatmospheric pressures.

Conclusions. The length and width of the U-shaped spillway crest and the shape of the crest profile were entirely satisfactory; therefore, both features are recommended for the prototype without change. However, the step in the chute floor appeared to have no beneficial effect; and for discharges near the maximum of 5,200 second feet, it was thought to be responsible for part of the surface roughness. Therefore, it was decided to eliminate the step before making further tests.

Chute Design No. 2

Description. In spillway Chute Design No. 2 only the chute floor was changed as shown in Figure 7. The step in the preliminary design was eliminated by raising the floor upstream from the step to the same slope as the floor downstream. The elevation of the floor at the upstream end and the downstream end was the same as in the preliminary design.

Flow characteristics. Flow in the chute of the double-side channel spillway is shown in Figure 14 for discharges of 3,100, 4,000, and 5,200 second feet. Flow was as smooth and uniform as for the preliminary design and even a little smoother in the vicinity of the former step.

Water surface profiles are shown in Figures 10 and 11 for discharges of 2,000, 3,100, and 5,200 second feet. The water surface followed the same pattern as for the preliminary design but was a little higher in the portion of the chute between the two crests. The higher water surface occurred because the chute floor was higher and not so steep.

Calibration. Discharge and coefficient of discharge curves obtained from the calibration tests of Design No. 2 are shown in Figure 11. The calibration tests showed that the higher water surface in the upstream chute submerged the crest at approximately 3,900 second feet. Therefore, approximately 0.6 of a foot more reservoir head was required to discharge 5,200 second feet than before. For discharges of 3,900 second feet or less, the discharge curve and coefficient of discharge curve were identical to the preliminary design.

Conclusions. The chute performed as well if not better than with the preliminary step design. However, Design No. 2 was abandoned because of the higher reservoir elevation required to discharge 5,200 second feet. It was decided to lower the upstream end of the chute so that a lower reservoir elevation would be required to discharge 5,200 second feet.

Chute Design No. 3

Description. Chute Design No. 3 is shown in Figure 7. The upstream end of the sloping chute floor was lowered 1 foot below that of the two previous designs. The elevation of the downstream end of the chute remained unchanged.

Flow characteristics. Flow in the chute of the double-side channel is shown in Figure 15 for discharges of 1,000, 3,100, 4,000, and 5,200 second feet. As in the preliminary design, flow conditions were excellent for all discharges except for some water surface roughness in the chute downstream from the double-side channel for emergency discharges near 5,200 second feet. However, the performance for these high discharges appeared to be improved over that in the preliminary design.

Water surface profiles were recorded for discharges of 2,000, 3,100, and 5,200 second feet as shown in Figures 10 and 11. The water surface in the upstream portion of the chute was lower than in Design No. 2 but still a little higher than in the preliminary design. In the downstream portion of the chute the water surface was lower than in the preliminary design.

Calibration. Discharge and coefficient of discharge curves obtained from the calibration data are shown in Figure 12. Up to approximately 4,300 second feet the curves are identical to those for the preliminary design. At approximately 4,300 second feet, the crest was submerged which is a slightly lower discharge than for the preliminary design. At the maximum discharge approximately 0.2 foot higher reservoir elevation was required to discharge the flow. However, approximately 0.4 foot less head was required than for Design No. 2. This alignment of the chute floor was, therefore, considered to be adequate by the designers.

Erosion. Since the crest and chute floor were satisfactory, tests were conducted on several variations in the deflector bucket at the downstream end of the chute. Five-minute erosion tests using 3/8-inch crushed rock in the movable bed were run with the design flow of 3,100 second feet to determine the trend of the erosion. Comparison of erosion patterns for various arrangements helped to evaluate each proposal.

a. No deflector.--First tests were made with no deflector. The erosion test in progress after 2 minutes and 5 minutes is shown in Figure 16 along with the erosion pattern after 5 minutes of operation. The erosion appeared to be extensive in the model, but this would not necessarily be true in the prototype since the prototype material is believed to be capable of resisting erosion better than the crushed rock used in the model. There was a definite tendency, though, to scour a deep hole near the end of the structure and this tendency would also be present in the prototype structure. The size and extent of the eroded hole are shown in Figure 17.

b. Preliminary deflector.--The preliminary deflector design was installed for the next tests. The discharge channel was molded to the elevation of the deflector lip or about 3 feet higher than in the previous test. It was hoped that the scour hole would occur farther from the structure.

A test shown in Figure 18 found that the flow was not deflected farther downstream because the velocity was too low. The deepest point in the scour hole actually occurred closer to the end of the structure than in the previous test when no deflector was used, as shown in Figure 17. The elevation of the deepest point, however, was about 3.5 feet higher than before since the elevation of the channel at the beginning of the test was 3 feet higher. The hole was also a little wider, but not so long as for the preceding test.

Recapitulation. Realigning the chute floor and removing the step made the chute easier to construct and provided satisfactory flow conditions throughout the structure. Although 0.2 foot more head was required to pass the maximum flood than with the preliminary design no difference was measurable for the usual flows up to 4,300 second feet. At the downstream end of the chute erosion occurred close to the structure whether or not a deflector was used. Therefore, the designers felt that it was necessary to extend the chute farther downstream so that the erosion would not endanger the nearby access road to the top of the dam shown in Figure 2.

Recommended Design

Description. The recommended design utilized the upstream portion of Chute Design No. 3 shown in Figure 7 but was extended approximately 100 feet farther downstream as shown in Figures 2 and 3. At the end of the longer chute a deflector was installed to direct the flow upward and away from the channel bed.

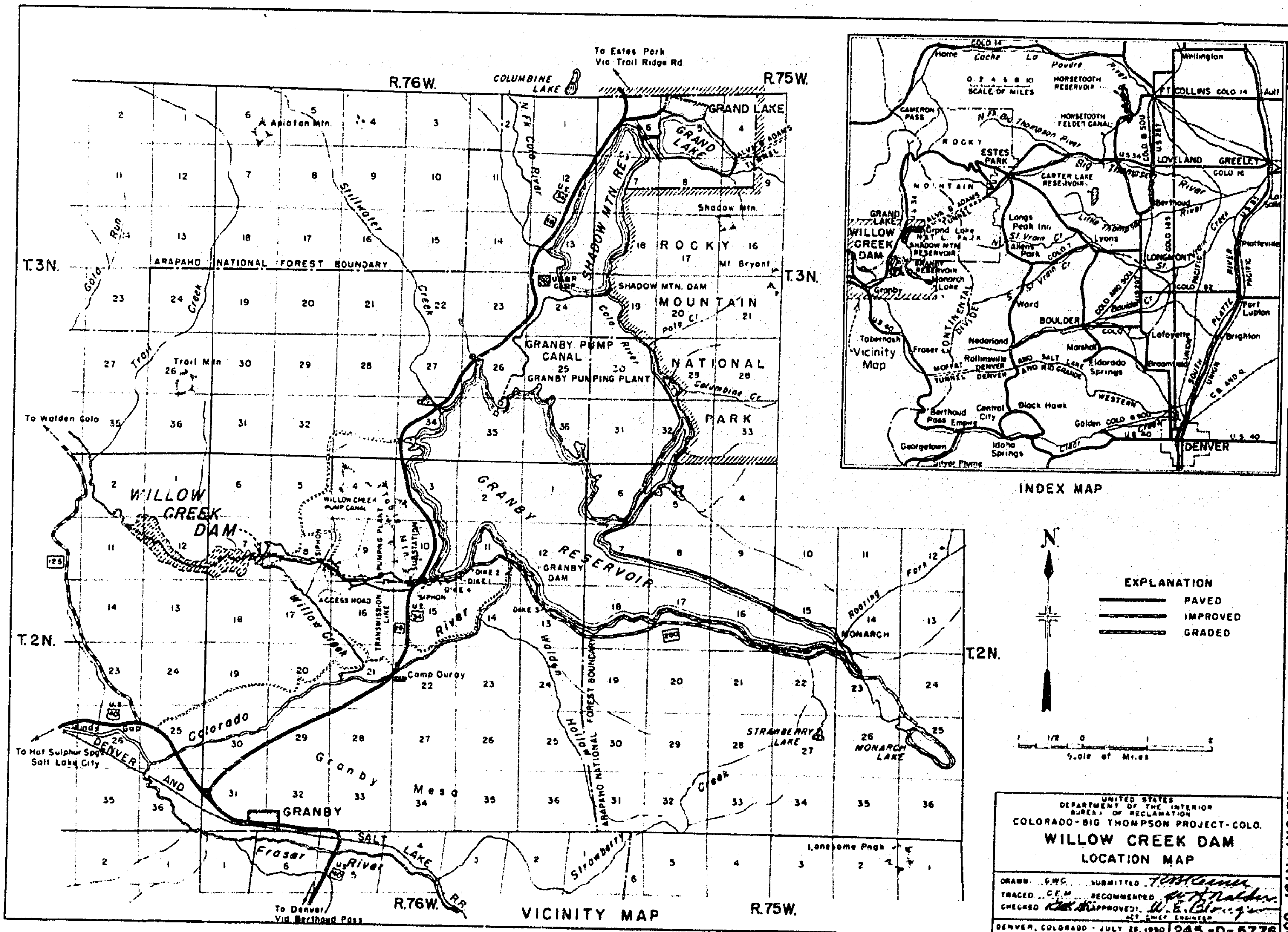
Flow characteristics, calibration, and erosion. The recommended design is shown operating in Figures 19 and 20. Flow in the double-side channel portion of the chute was not changed from that in Design No. 3 shown in Figure 15. Therefore, water surface profiles in that portion of the chute, Figures 10 and 11, and the discharge calibration, Figure 12, were the same for the recommended design as for Design No. 3.

Water surface profiles were recorded in the extended portion of the chute along the center line and the left training wall for use in determining training wall heights. Profiles were recorded for discharges of 3,100 and 5,200 second feet, shown in Figure 21. Transverse profiles were recorded at several stations as shown in Figure 22. Erosion at the end of the structure was similar to that for Design No. 3. Spillway Design No. 3 with the longer chute, as shown in Figure 3, is, therefore, recommended for the prototype.

Spillway Approach

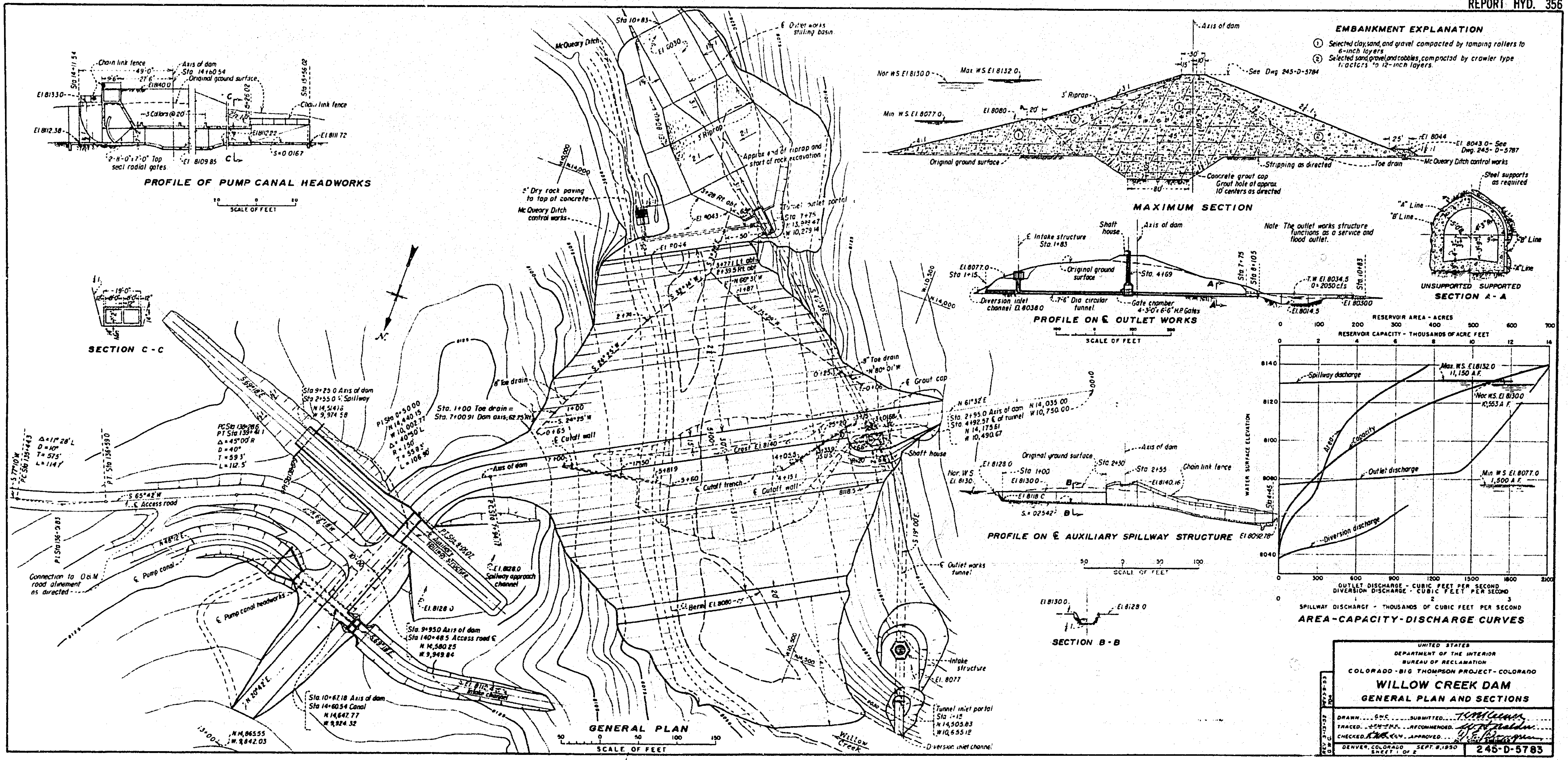
The spillway approach area is shown in Figure 2. The model investigation disclosed a slight disturbance in the water surface around the left inlet training wall for the design flow of 3,100 second feet and a greater disturbance for the maximum emergency discharge of 5,200 second feet as shown in Figure 23. These disturbances were considered to be minor. Since there was little to be gained by eliminating them, except improved appearance, no changes in the preliminary design were recommended in the approach.

As a matter of interest and for aiding in future designs, the flow currents approaching the spillway were photographed for several discharges as shown in Figures 24 and 25. The currents were photographed using confetti on the water surface in a time exposure. The length of the confetti streaks indicates the comparative velocities as well as the direction of flow. Note that where the crest is not submerged the flow currents pass over the crest at nearly right angles to the crest axis.



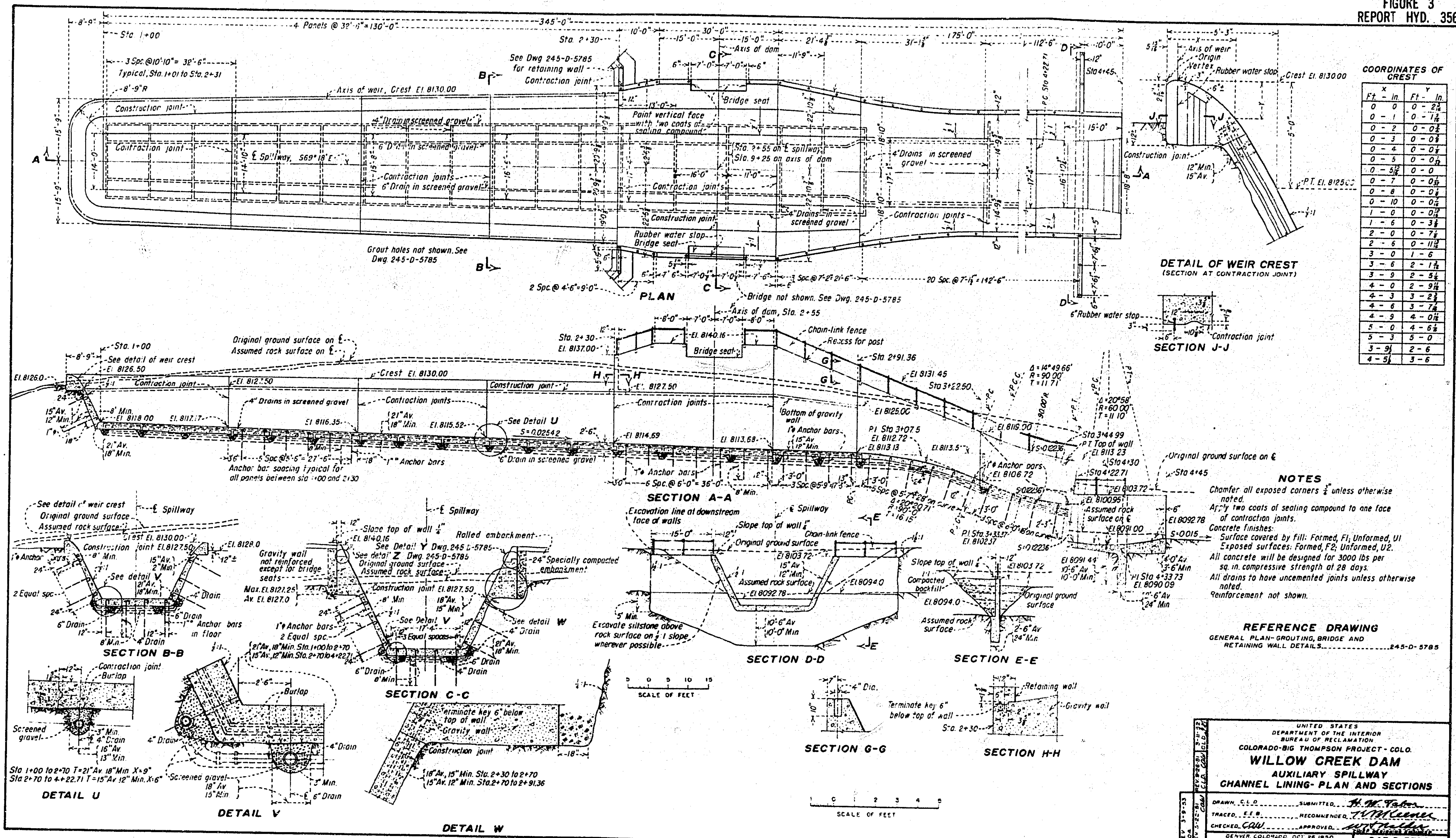
RECORD DRAWING

FIGURE 1
REPORT HYD. 356



RECORD DRAWING

FIGURE 3
REPORT HYD. 356



COORDINATES OF CREST

X Ft. - In.	Y Ft. - In.
0 0	0 - 2 3/16
0 - 1	0 - 1 5/16
0 - 2	0 - 0 5/8
0 - 3	0 - 0 3/8
0 - 4	0 - 0 1/8
0 - 5	0 - 0 1/32
0 - 5 15/16	0 - 0
0 - 7	0 - 0 7/32
0 - 8	0 - 0 1/8
0 - 10	0 - 0 7/16
1 - 0	0 - 0 13/16
1 - 6	0 - 3 1/8
2 - 0	0 - 7 1/8
2 - 6	0 - 11 13/16
3 - 0	1 - 6
3 - 6	2 - 1 3/16
3 - 9	2 - 5 1/4
4 - 0	2 - 9 11/16
4 - 3	3 - 2 3/8
4 - 6	3 - 7 7/8
4 - 9	4 - 0 11/16
5 - 0	4 - 6 1/8
5 - 3	5 - 0
3 - 9 1/2	2 - 6
4 - 5 1/2	3 - 6

NOTES

Chamfer all exposed corners 3/4" unless otherwise noted.
Apply two coats of sealing compound to one face of contraction joints.
Concrete finishes:
Surface covered by fill: Formed, F1; Unformed, U1
Exposed surfaces: Formed, F2; Unformed, U2.
All concrete will be designed for 3000 lbs per sq. in. compressive strength at 28 days.
All drains to have uncemented joints unless otherwise noted.
Reinforcement not shown.

REFERENCE DRAWING

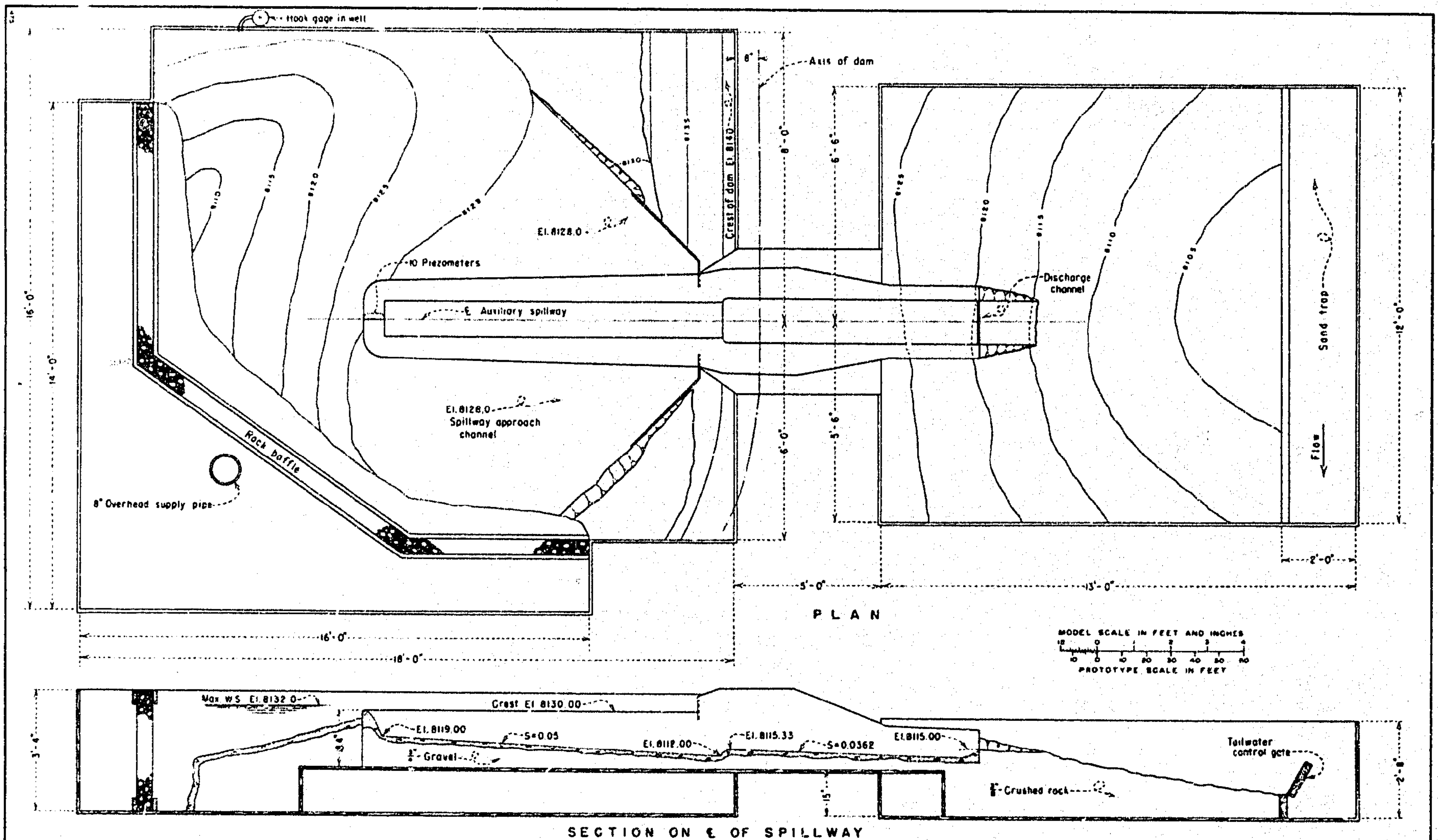
GENERAL PLAN-GROUTING, BRIDGE AND RETAINING WALL DETAILS 245-D-5785

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO-BIG THOMPSON PROJECT - COLO.

WILLOW CREEK DAM
AUXILIARY SPILLWAY
CHANNEL LINING - PLAN AND SECTIONS

DRAWN C.L.O. SUBMITTED H. W. Fales
TRACED E.E.B. RECOMMENDED
CHECKED CAW APPROVED
DENVER, COLORADO, OCT. 26, 1950
245-D-5786

RECORD DRAWING

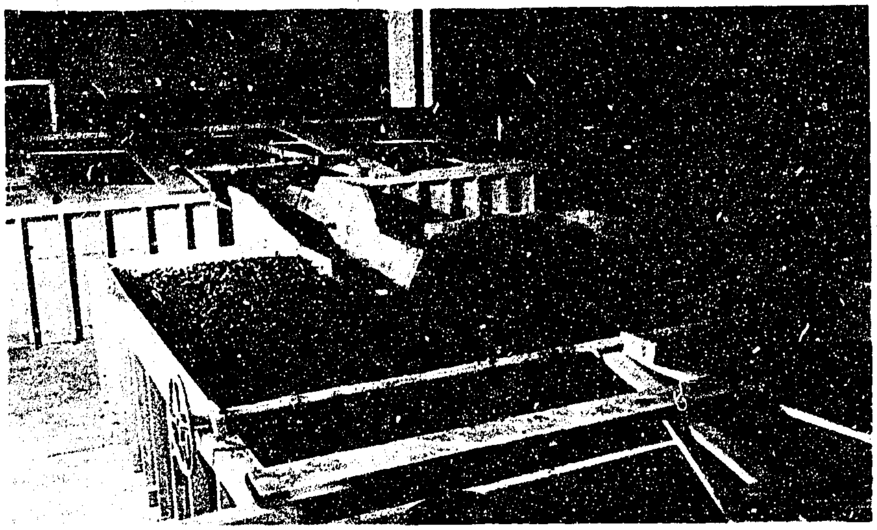


WILLOW CREEK DAM - AUXILIARY SPILLWAY

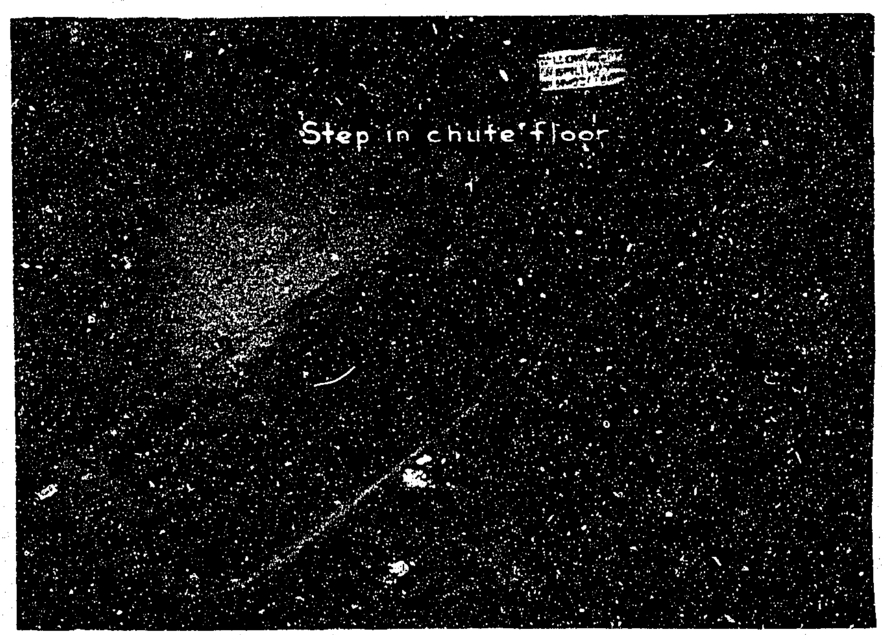
MODEL LAYOUT - PRELIMINARY DESIGN

1:15 SCALE MODEL

FIGURE 4
REPORT HYD. 334



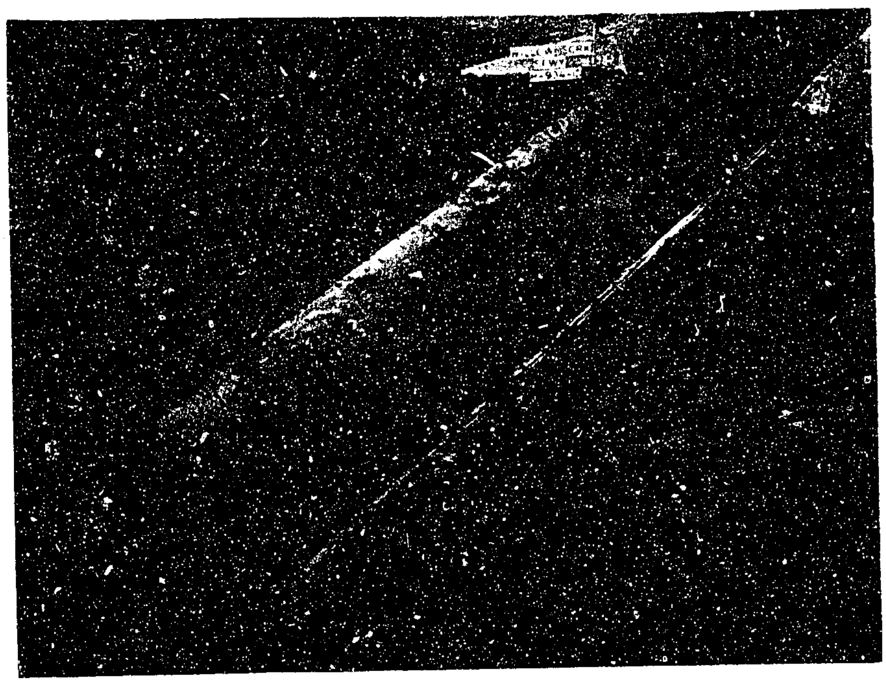
Model layout



U-shaped double side channel spillway

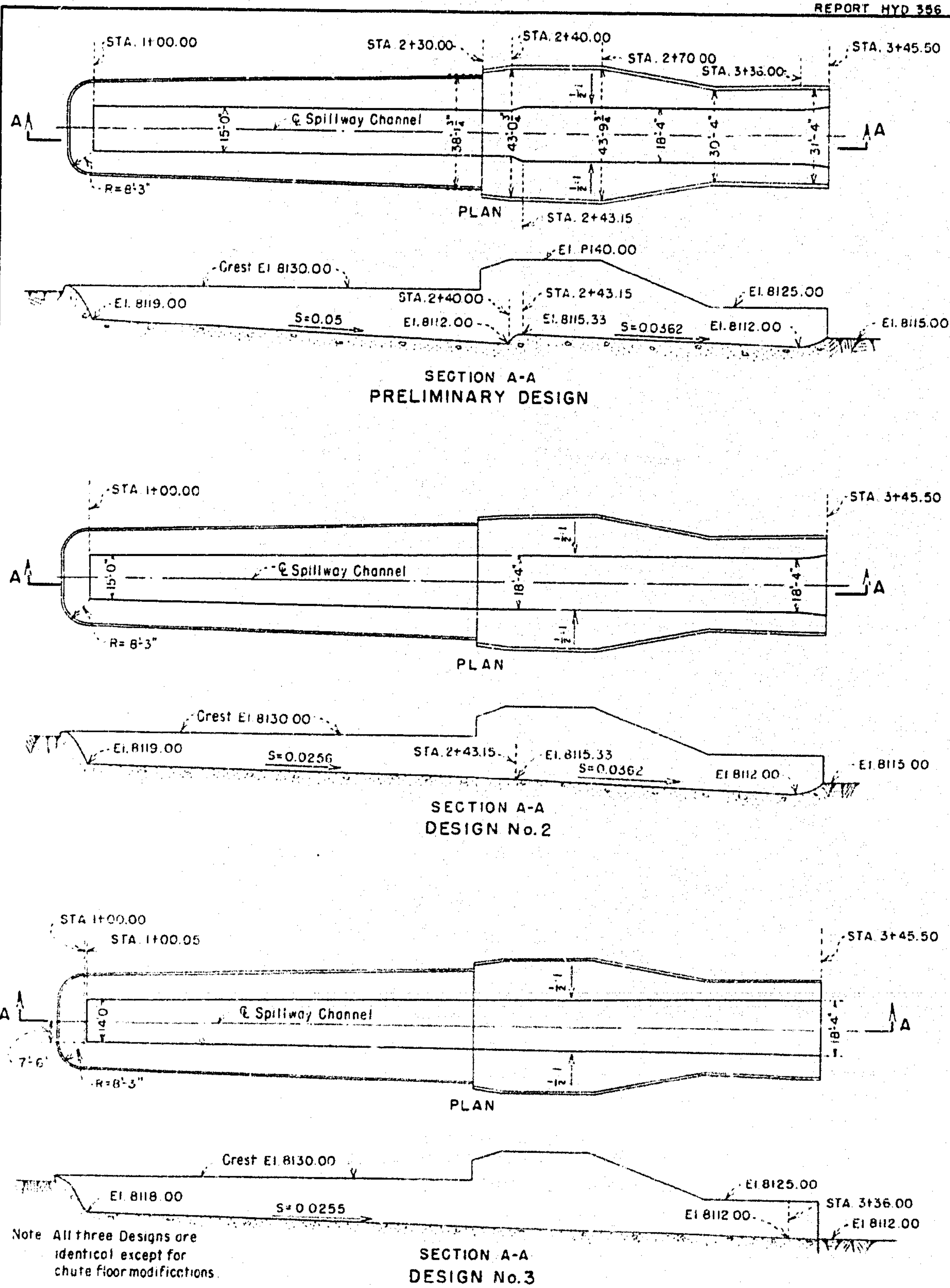
WILLOW CREEK DAM AUXILIARY SPILLWAY
Model Views--Preliminary Design
1:15 Scale Model

Spillway with extended chute



U-shaped double side channel spillway

WILLOW CREEK DAM AUXILIARY SPILLWAY
Model Views--Recommended Design
1:15 Scale Model



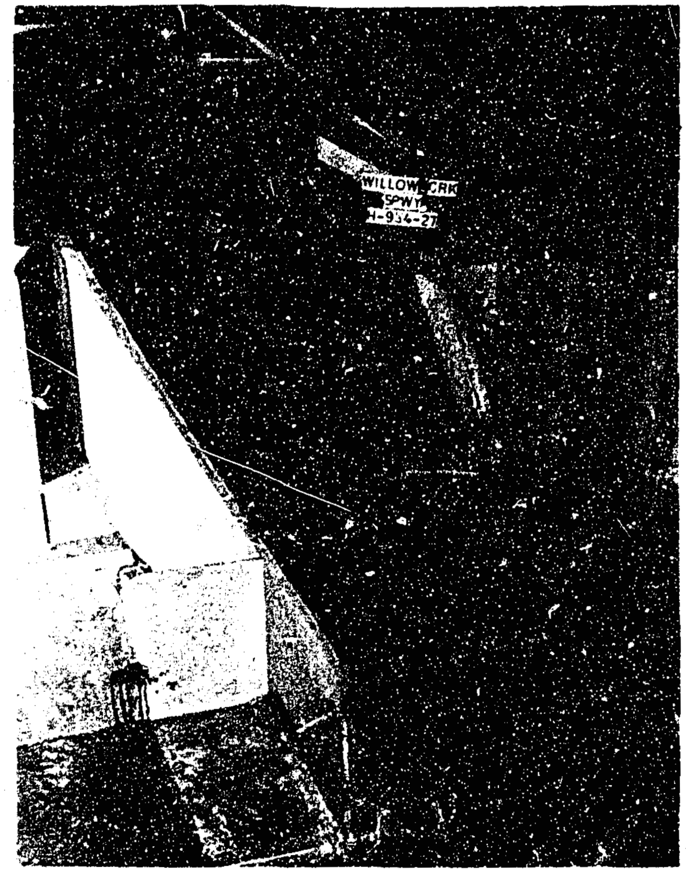
WILLOW CREEK DAM AUXILIARY SPILLWAY

SPILLWAY CHUTE DESIGNS TESTED

1:15 SCALE MODEL

475

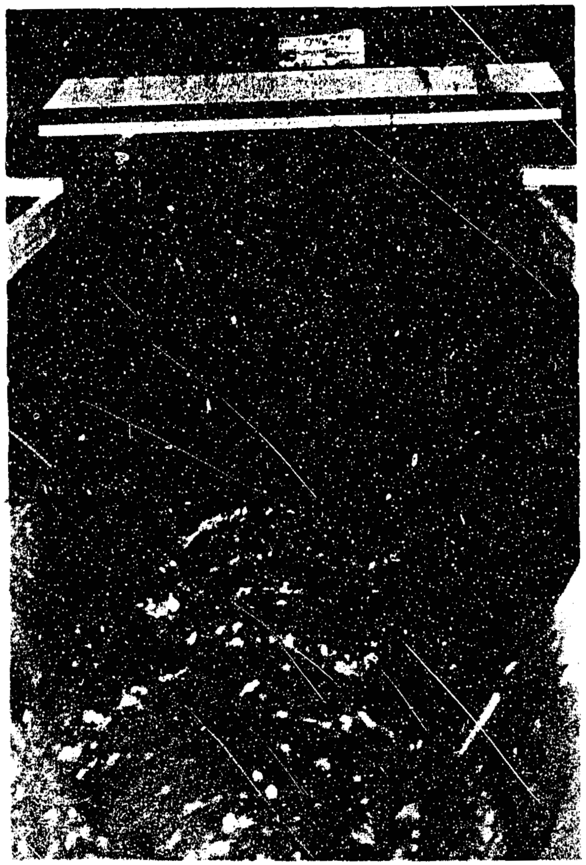
Design discharge 3, 100 second-feet



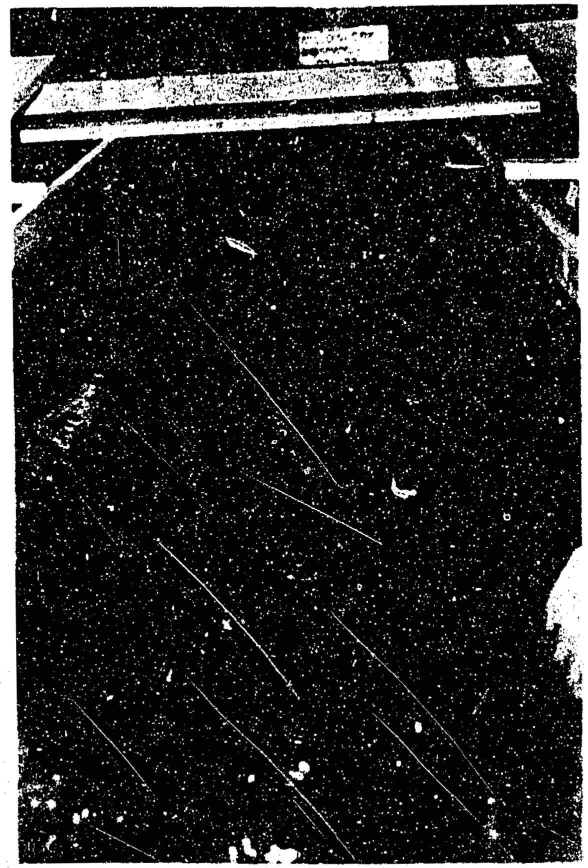
5, 200 second-feet

WILLOW CREEK DAM AUXILIARY SPILLWAY
Preliminary Design--Flow Through The Structure
1:15 Scale Model

Figure 8
Report Hyd 356



Design discharge 3,100 second-feet

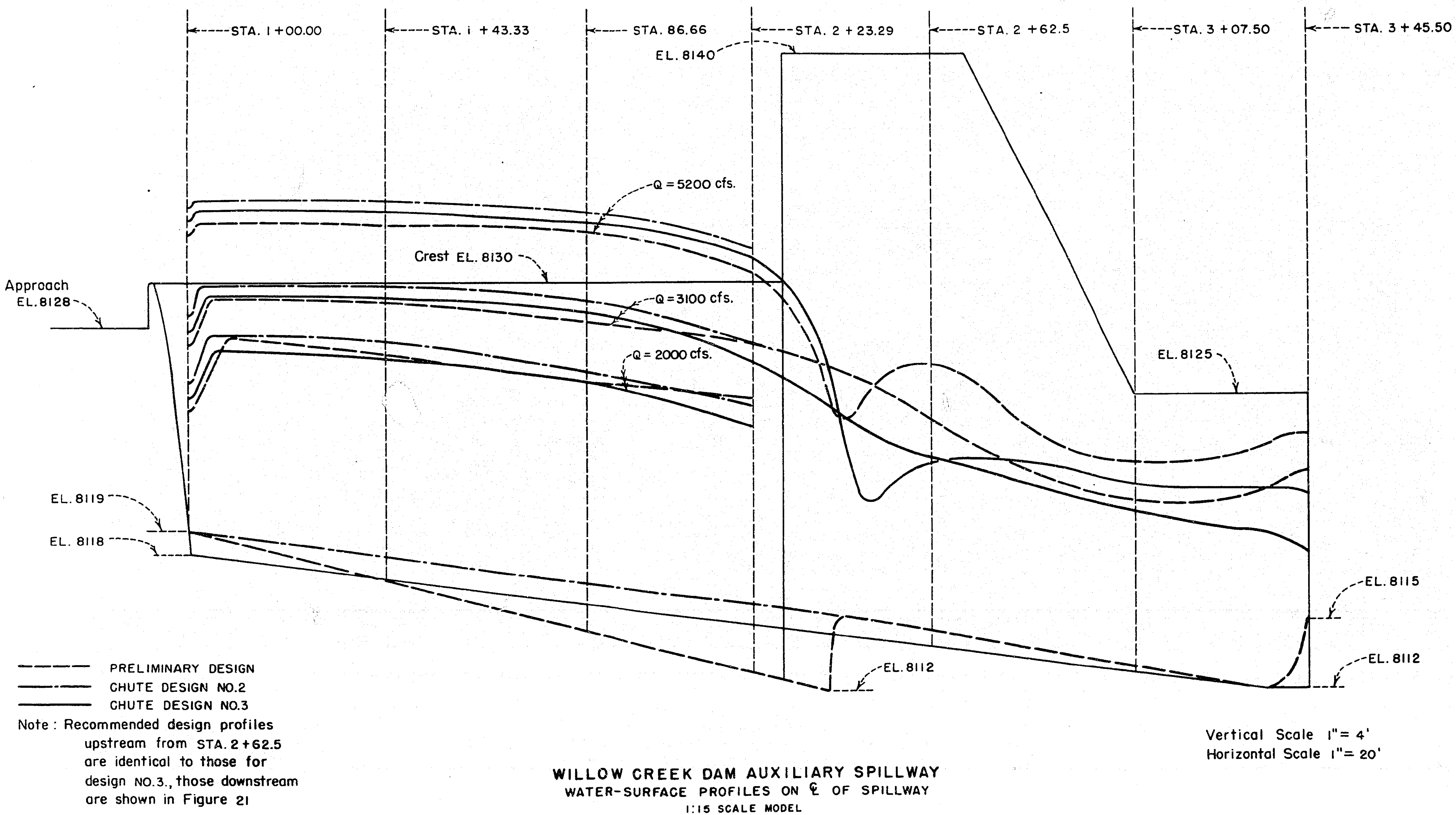


4,000 second-feet

5,200 second-feet

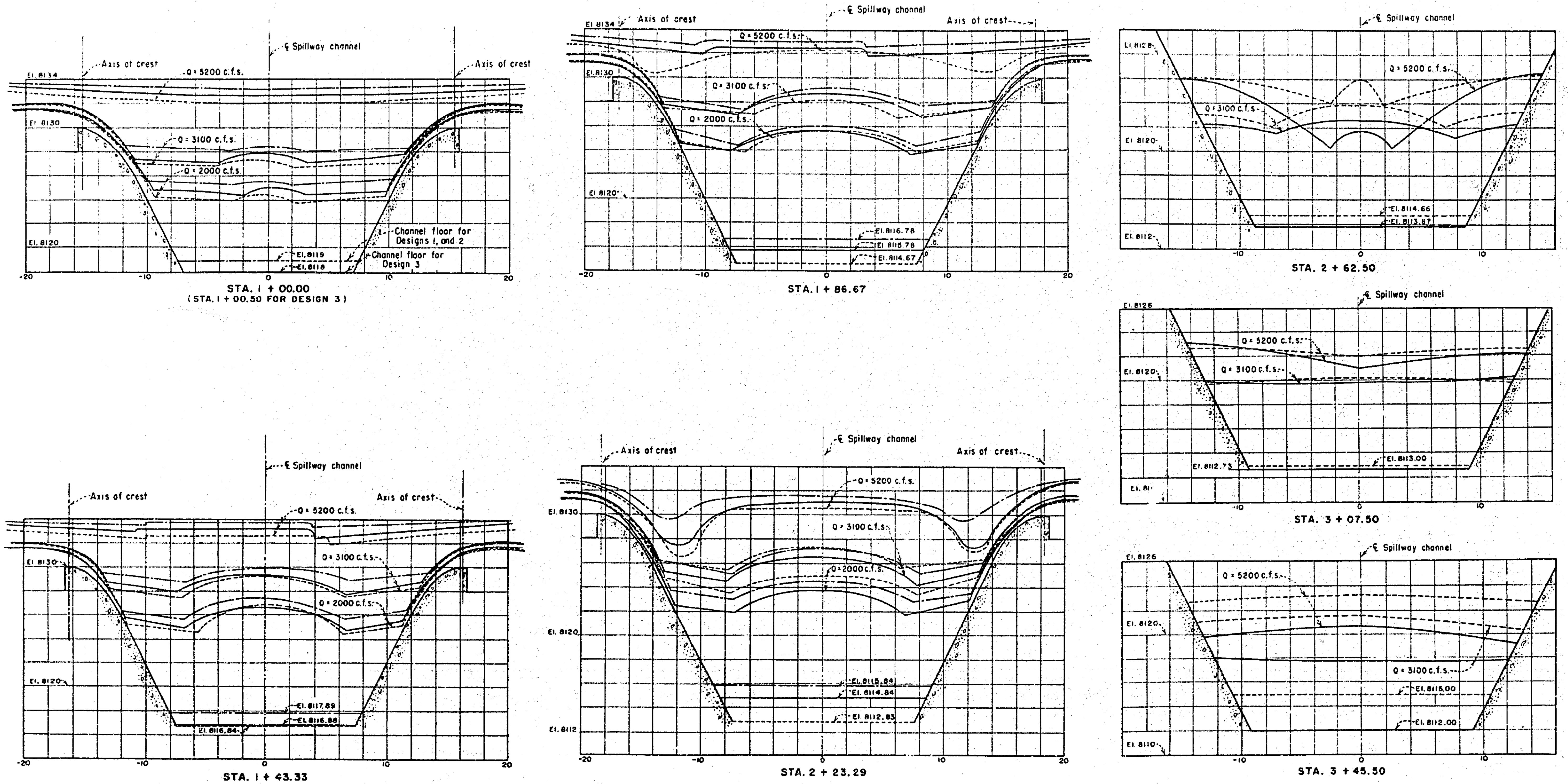
WILLOW CREEK DAM AUXILIARY SPILLWAY
Preliminary Design--Flow In The Double Side Channel Chute
1:15 Scale Model

Figure 9
Report Hyd 356



WILLOW CREEK DAM AUXILIARY SPILLWAY
WATER-SURFACE PROFILES ON ℄ OF SPILLWAY
1:15 SCALE MODEL

475



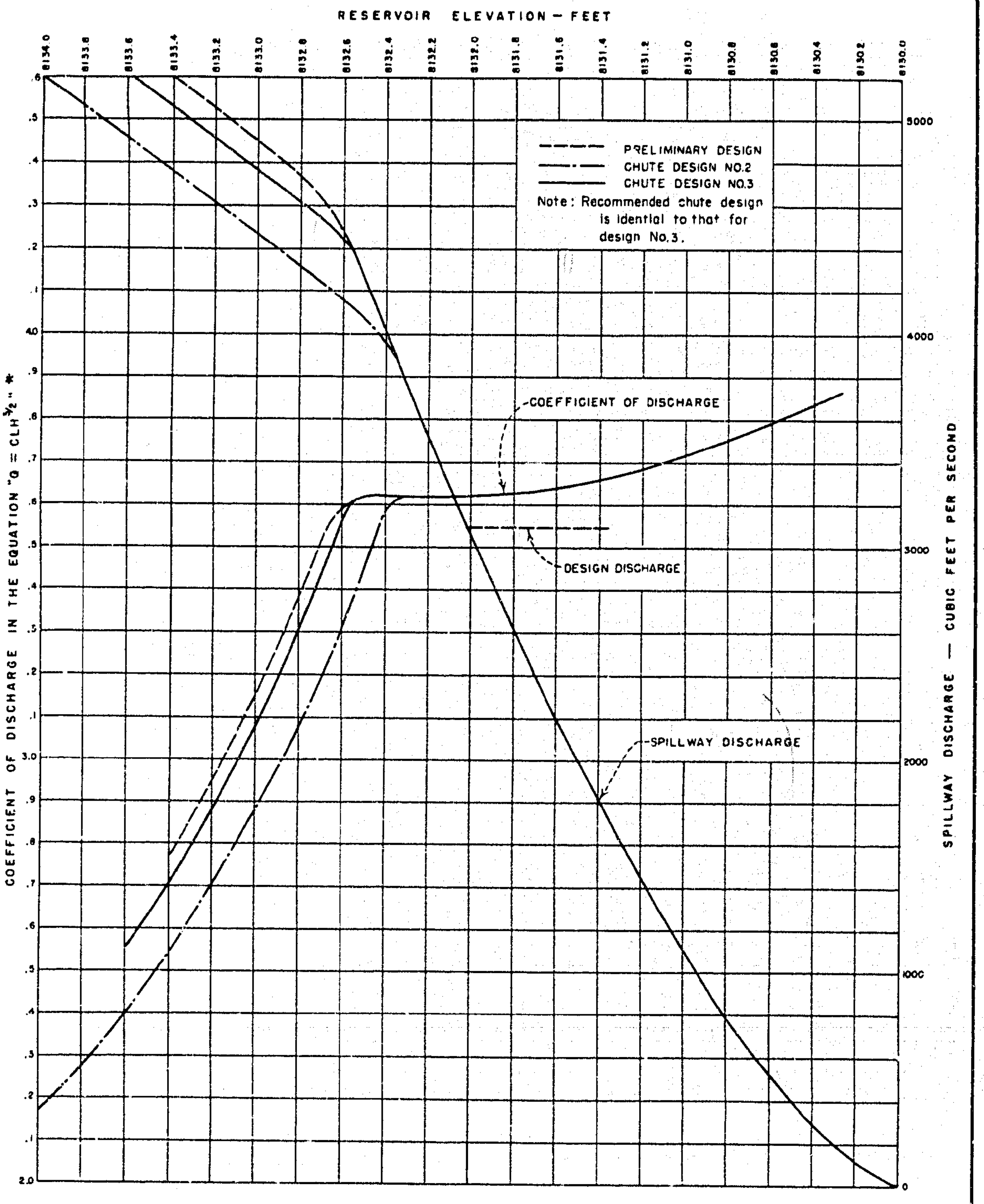
NOTES

Recommended design profiles at stations upstream from 2 + 62.5 are identical to those for design No. 3, those at stations downstream are shown in figure 22.
All sections are taken looking downstream.

WILLOW CREEK DAM AUXILIARY SPILLWAY
SECTIONAL WATER SURFACE PROFILES
1:15 SCALE MODEL

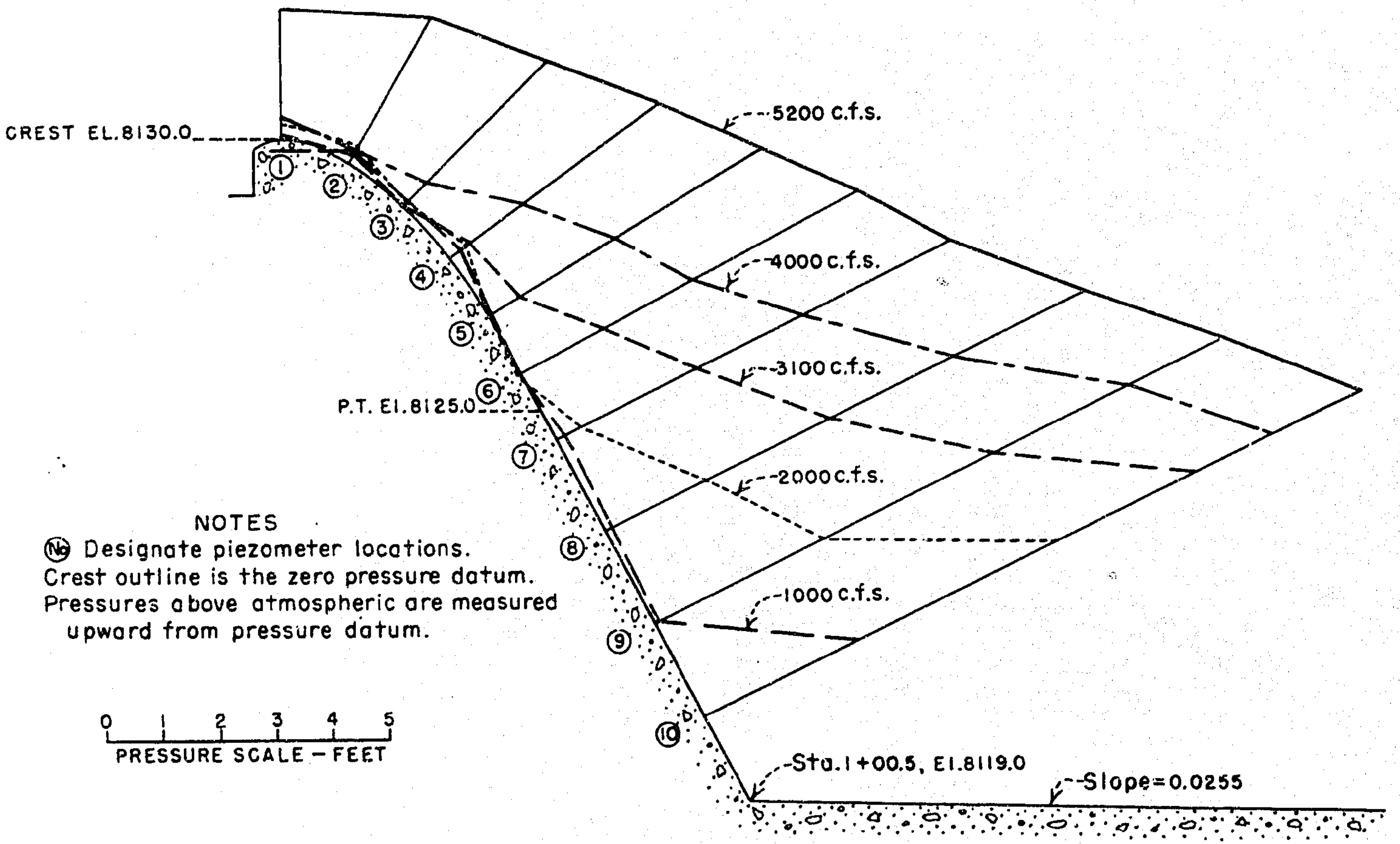
SYMBOLS

Preliminary design ----------
Chute design No. 2 —-—-—
Chute design No. 3 ————



* Note: Lenght of Spillway Crest "L" is measured along the crest axis at El. 8130.

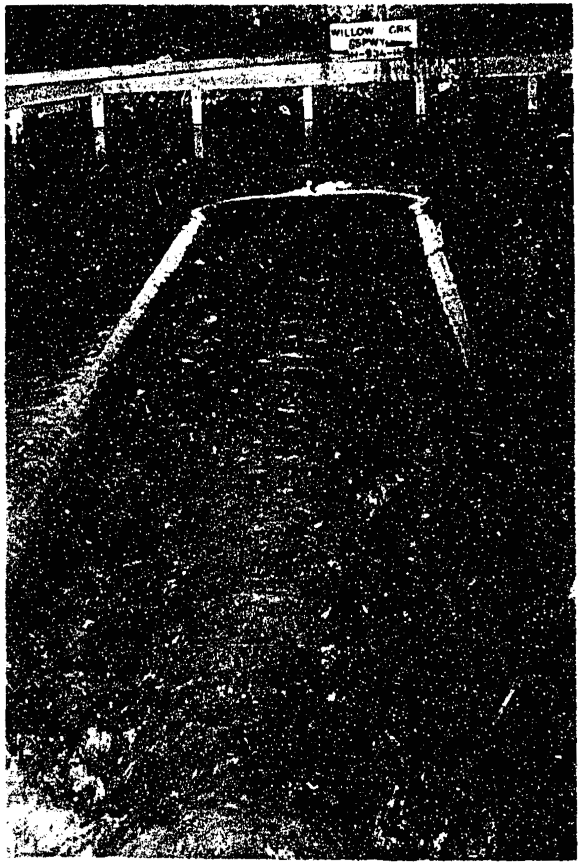
WILLOW CREEK DAM AUXILIARY SPILLWAY
SPILLWAY DISCHARGE AND COEFFICIENT OF DISCHARGE CURVES
1:15 SCALE MODEL



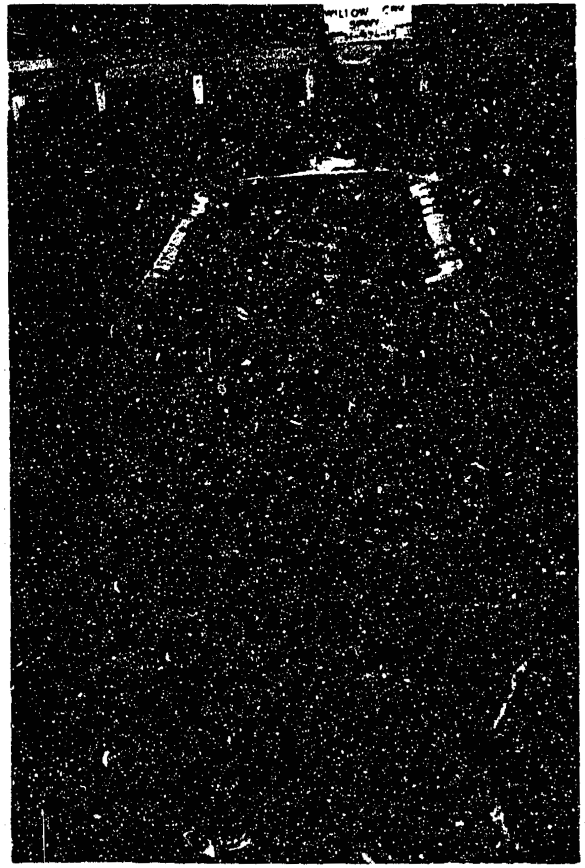
WILLOW CREEK DAM AUXILIARY SPILLWAY

CREST PRESSURES

1:15 MODEL



Design discharge 3, 100 second-feet

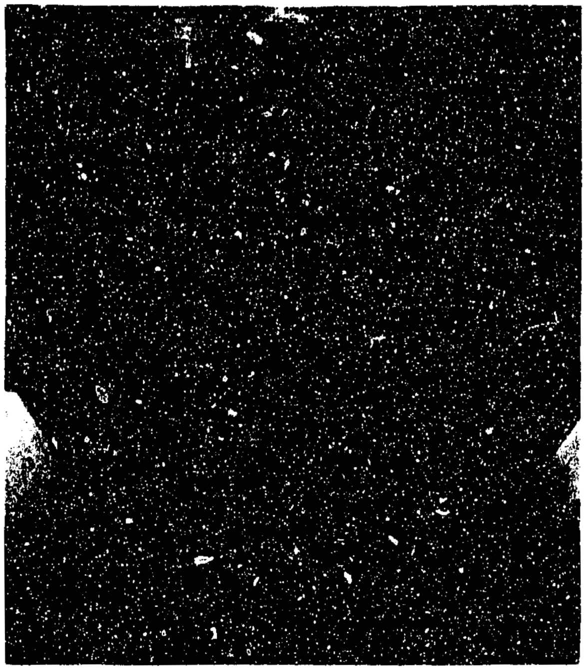


4, 000 second-feet

5, 200 second-feet

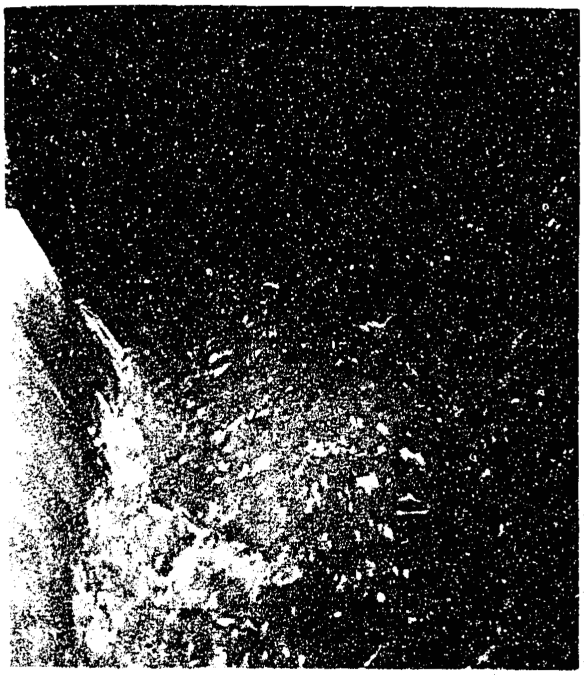
WILLOW CREEK DAM AUXILIARY SPILLWAY
Flow Through Double Side Channel Chute of Design No. 2
1:15 Scale Model

Figure 14
Report Hyd 358

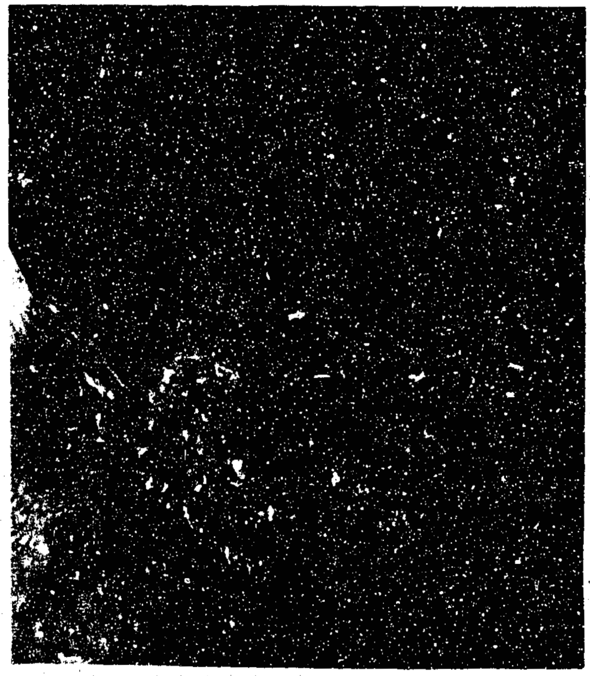


1, 000 second-feet

3, 100 second-feet



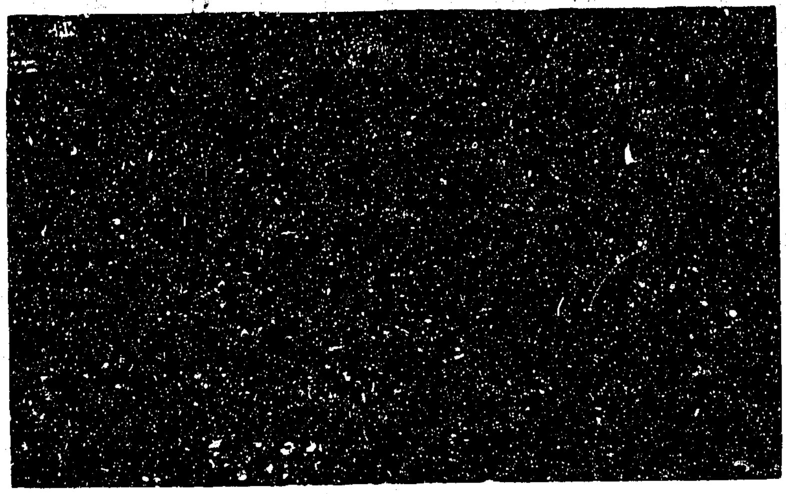
4, 000 second-feet



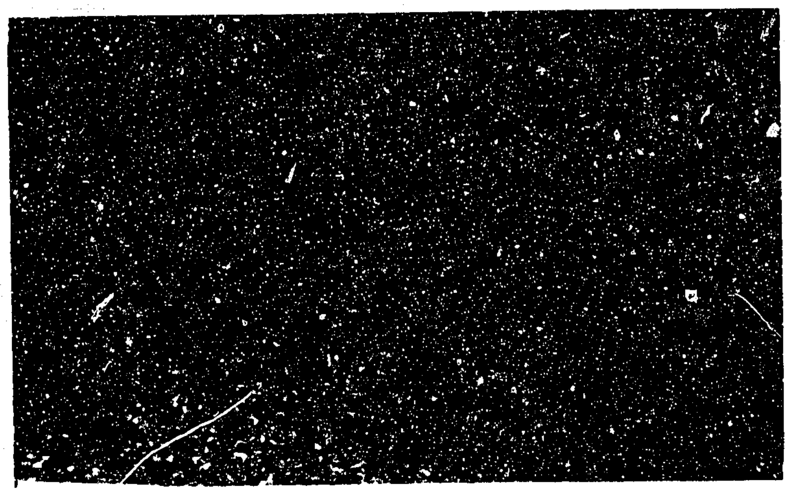
5, 200 second-feet

Note: This portion of the chute is the same for the Recommended Design as for Design No. 3.

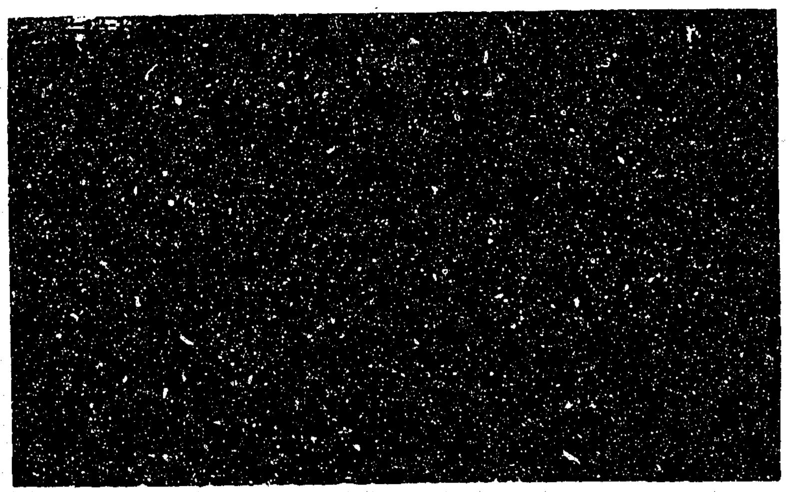
WILLOW CREEK DAM AUXILIARY SPILLWAY
Flow Through The Double Side Channel Chute
Of Design No. 3 and Recommended Design
1:15 Scale Model



Flow appearance after 2 minutes operation

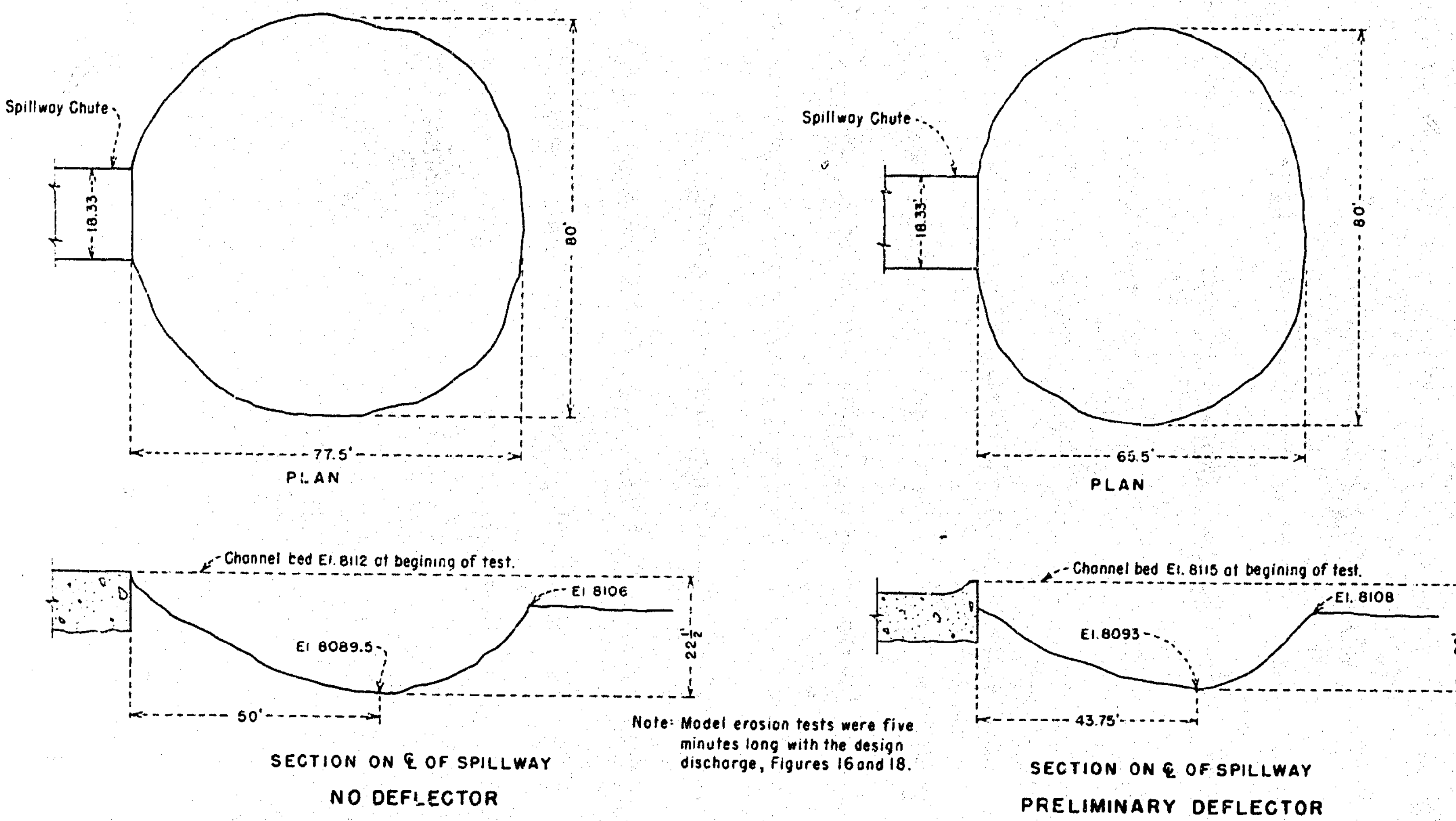


Flow appearance after 5 minutes operation



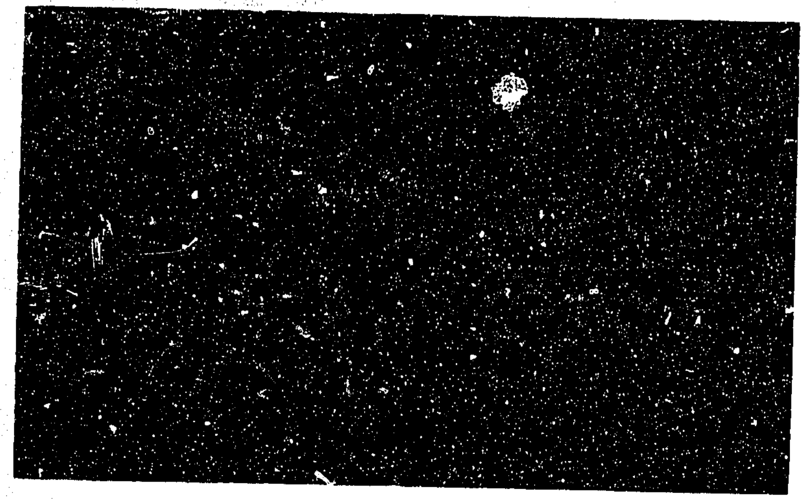
Erosion after 5 minute model test

WILLOW CREEK DAM AUXILIARY SPILLWAY
Erosion Test--Chute Design No. 3 With No Deflector
Design Discharge 3, 100 Second-feet
1:15 Scale Model

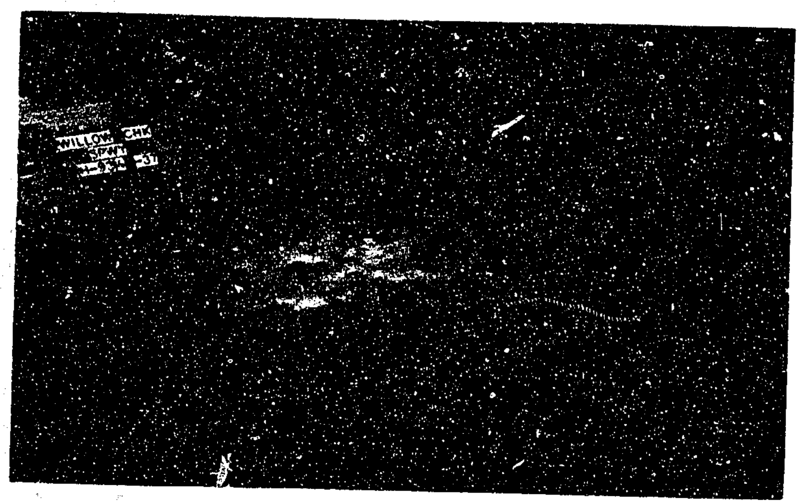


WILLOW CREEK DAM AUXILIARY SPILLWAY
EROSION MEASUREMENTS WITH AND WITHOUT DEFLECTOR
1:15 SCALE MODEL

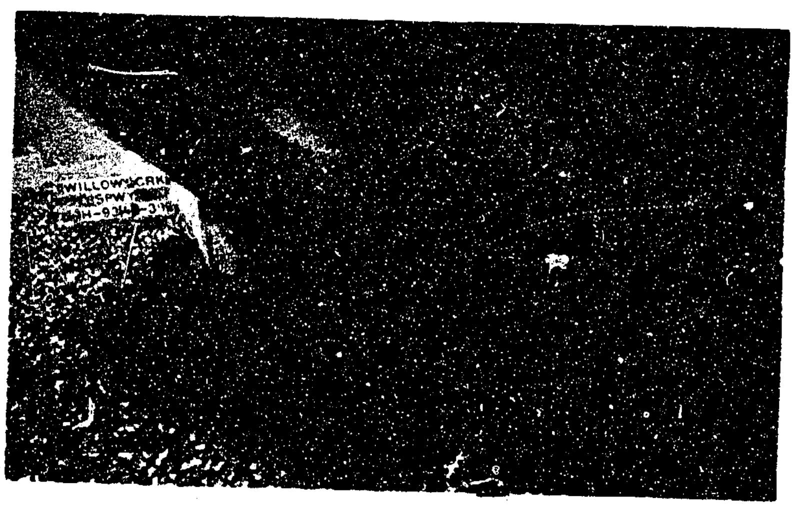
FIGURE 17
REPORT HYD 356



Flow appearance after 2 minutes operation

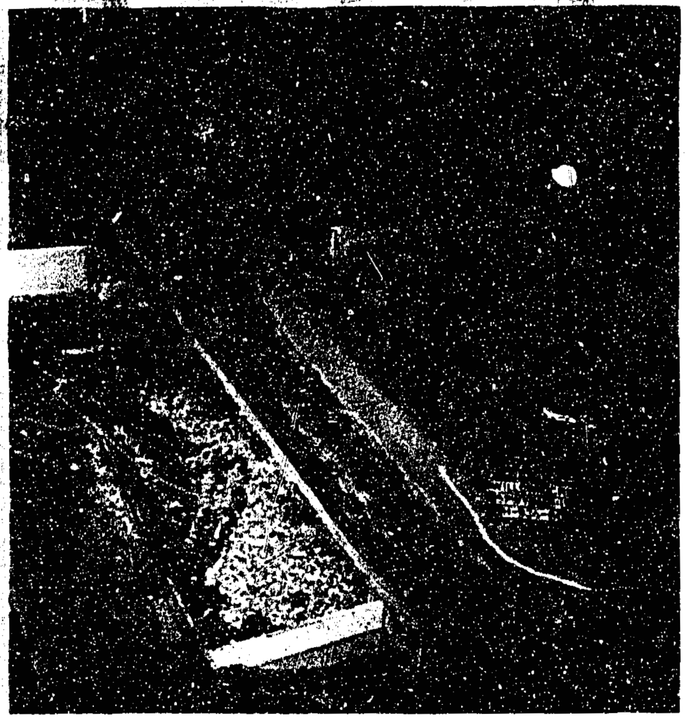


Flow appearance after 5 minutes operation



Erosion after 5 minutes model test

WILLOW CREEK DAM AUXILIARY SPILLWAY
Erosion Test--Chute Design No. 3 With Preliminary Deflector
Design Discharge 3,100 Second-feet
1:15 Scale Model



Flow in extended chute - recommended deflector

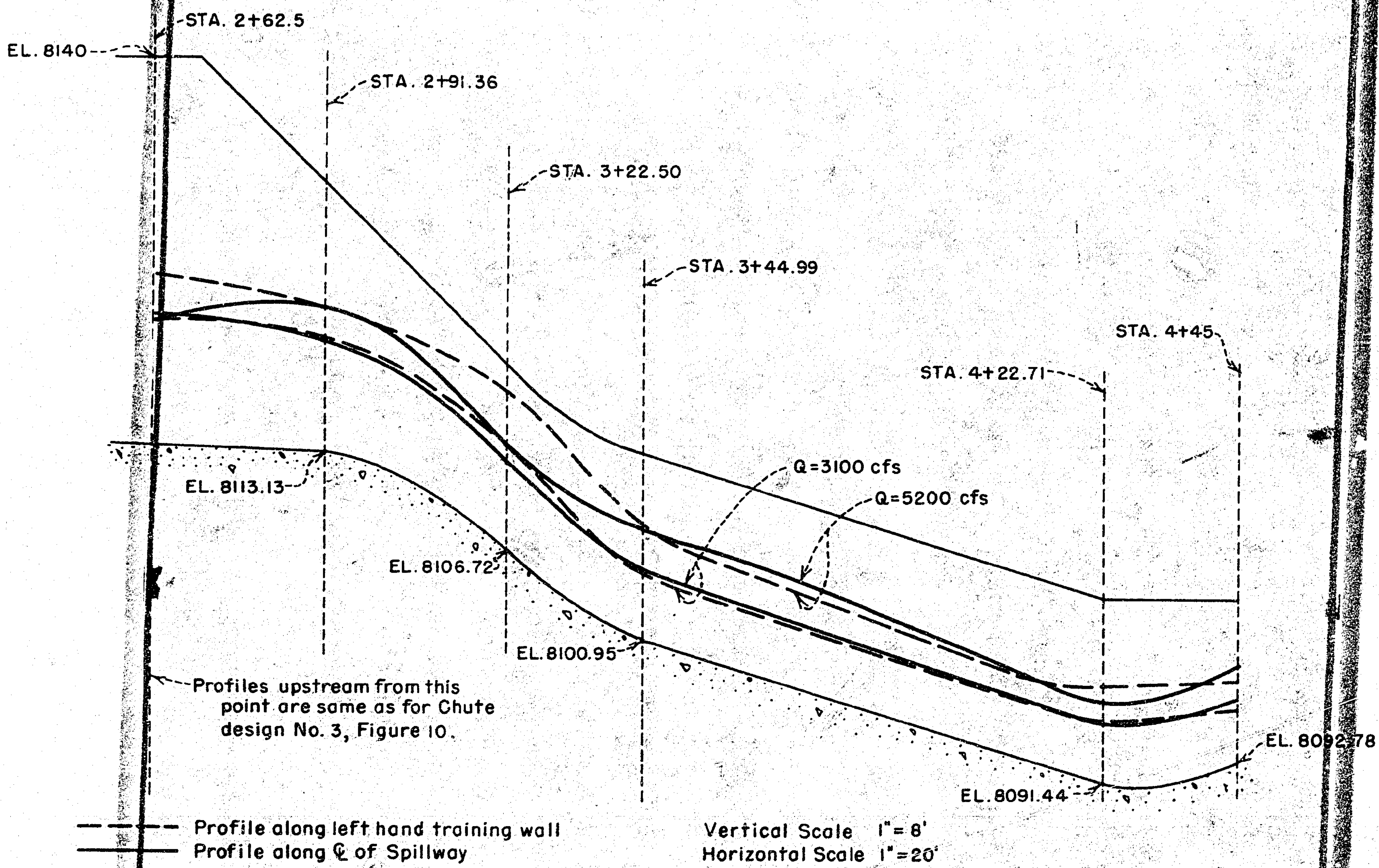
Flow in chute

WILLOW CREEK DAM AUXILIARY SPILLWAY
Recommended Design--Flow Through The Structure
Design Discharge 3,100 Second-feet
1:15 Scale Model

Flow in extended chute -- recommended deflector

Flow in chute

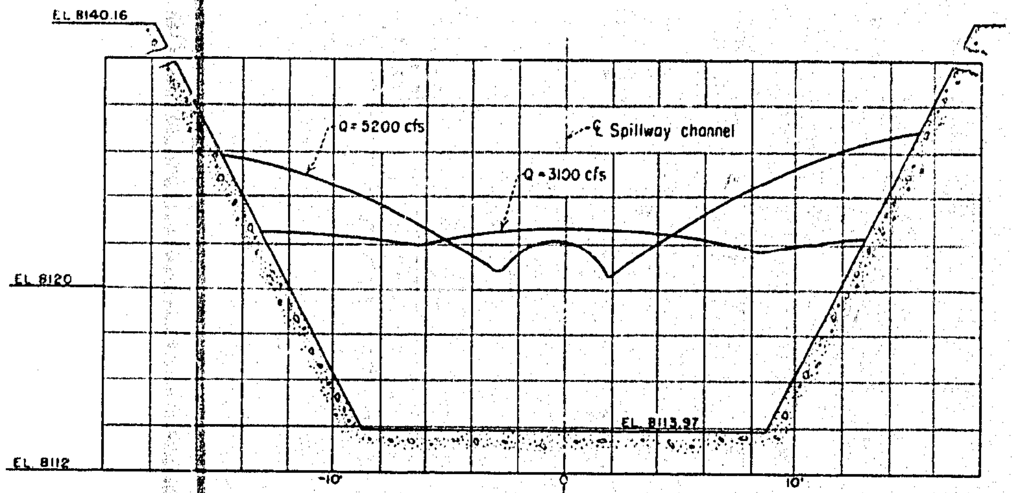
WILLOW CREEK DAM AUXILIARY SPILLWAY
Recommended Design--Flow Through The Structure
5,200 Second-feet
1:15 Scale Model



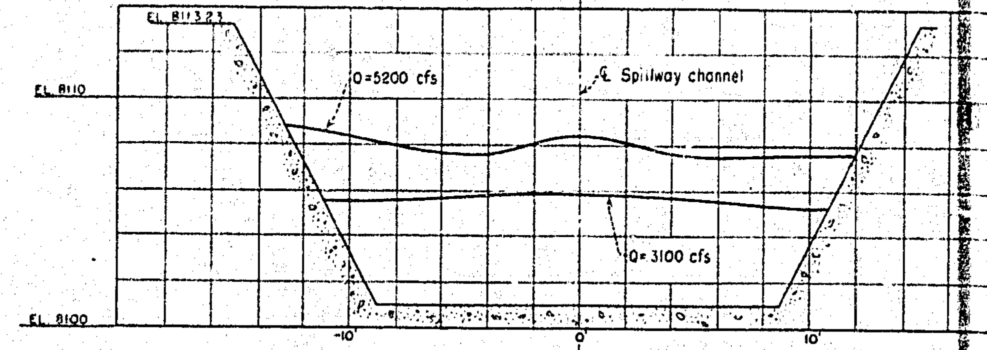
WILLOW CREEK DAM AUXILIARY SPILLWAY
WATER SURFACE PROFILES
RECOMMENDED DESIGN
1:15 SCALE MODEL

475

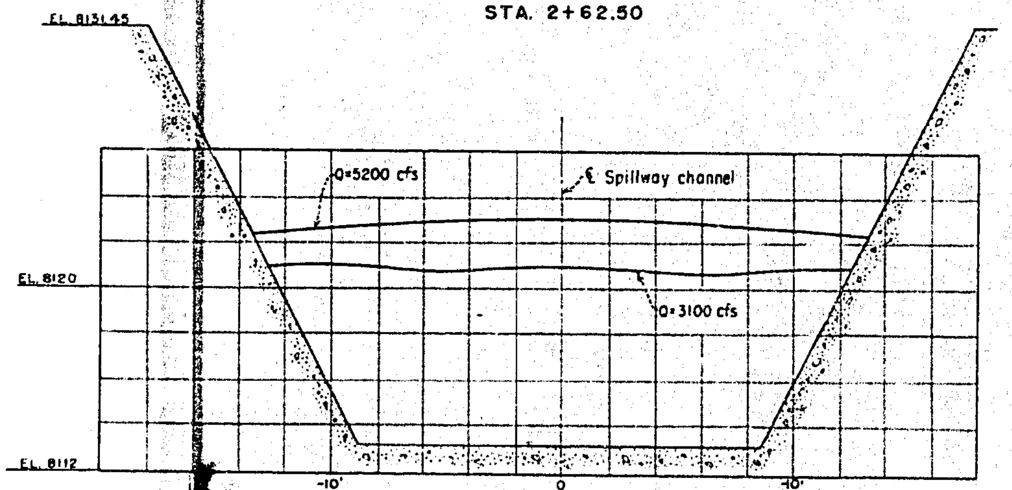
FIGURE 22
REPORT HYD 356



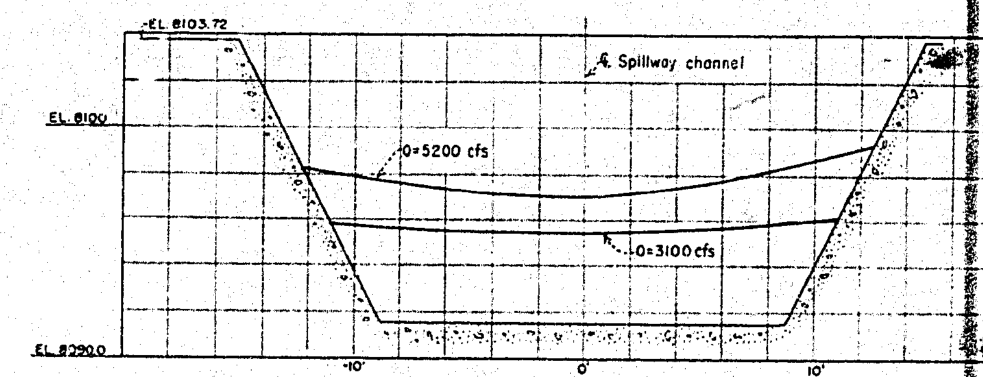
STA. 2+62.50



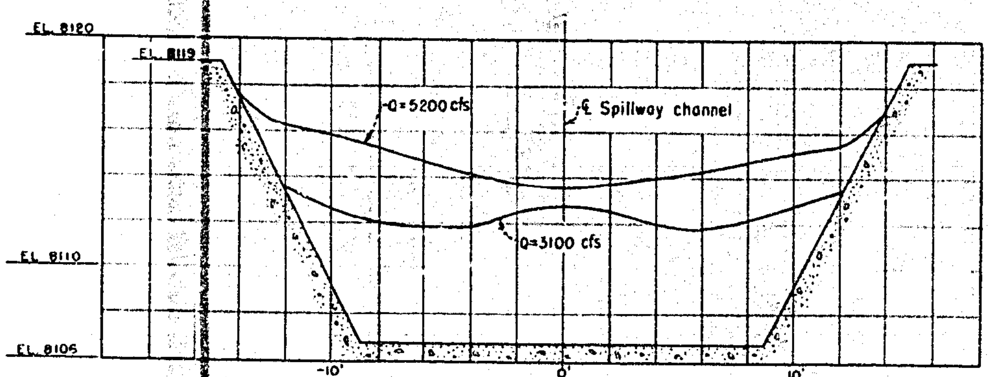
STA. 3+44.99



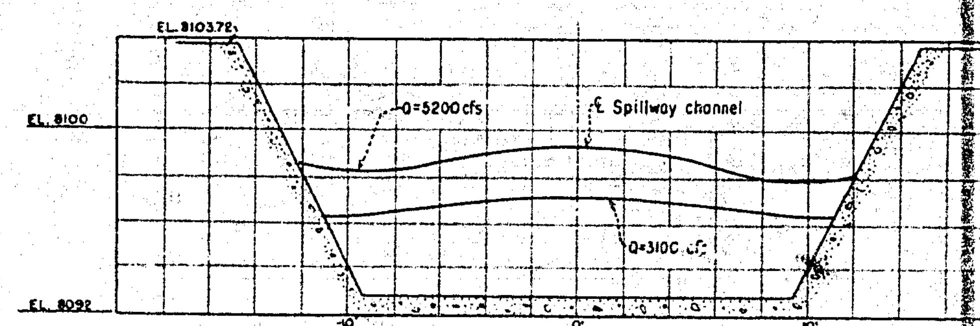
STA. 2+91.36



STA. 4+22.71



STA. 3+22.50



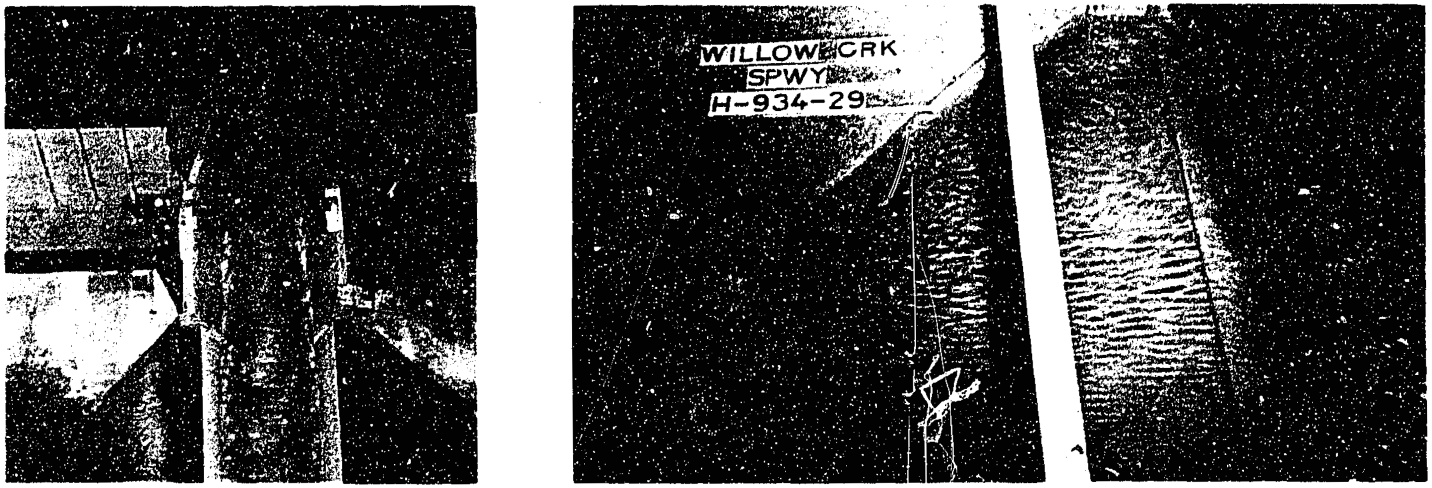
STA. 4+45

NOTE

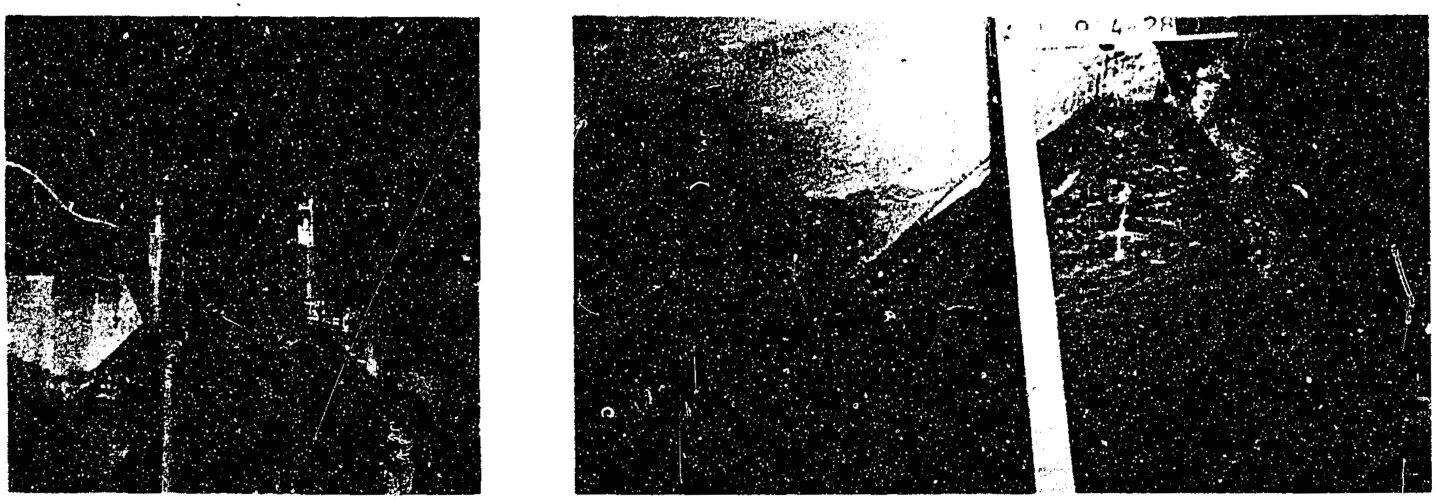
All sections are taken looking downstream
Sectional profiles upstream from Sta. 2+62.5
are same as for design No. 3, figure 17.

WILLOW CREEK DAM AUXILIARY SPILLWAY
SECTIONAL WATER SURFACE PROFILES
RECOMMENDED SPILLWAY DESIGN
1:15 SCALE MODEL

475



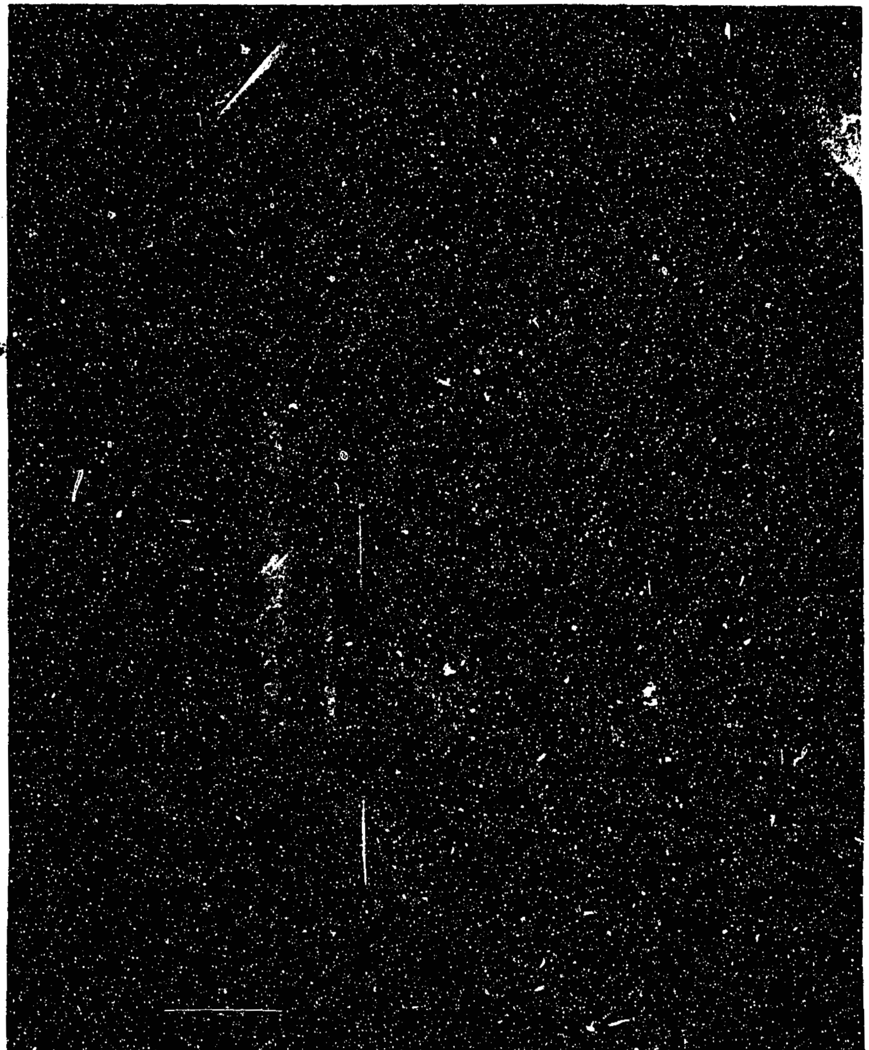
Design discharge - 3,100 second-feet



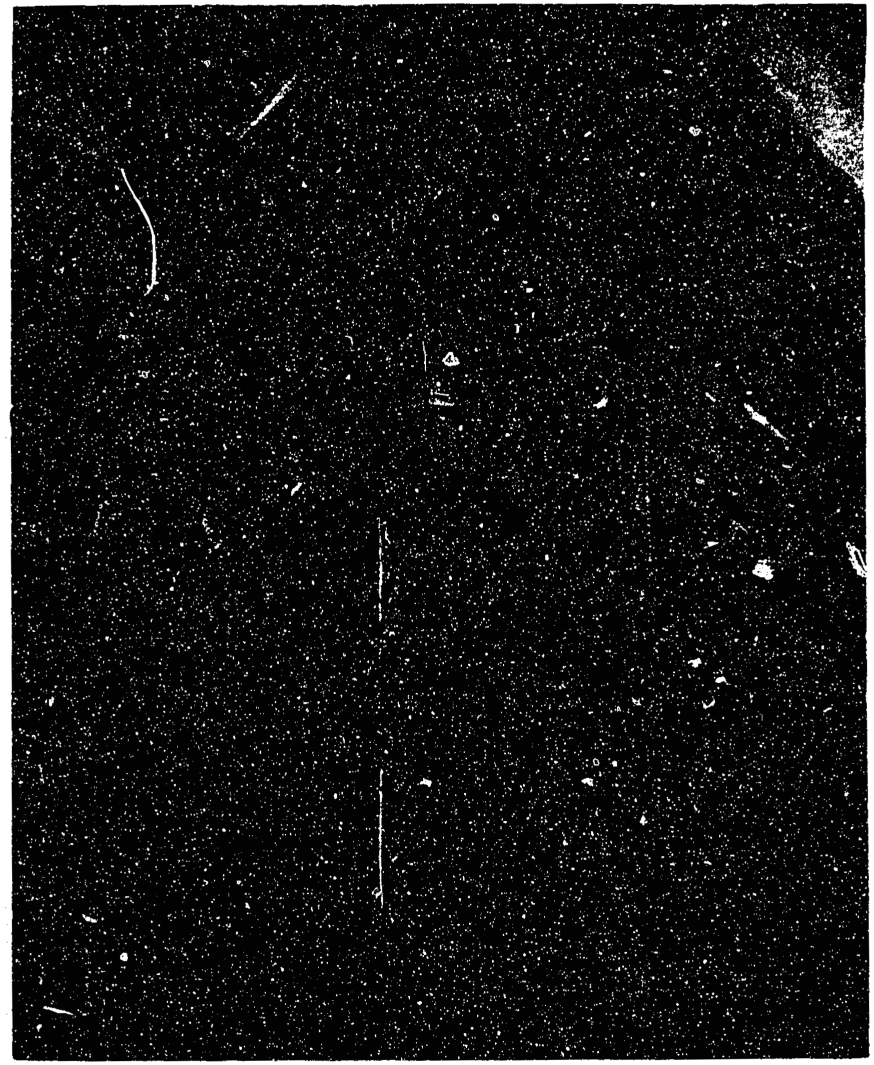
5,200 second-feet

WILLOW CREEK DAM AUXILIARY SPILLWAY
Flow In The Spillway Approach
1:15 Scale Model

Figure 23
Report Hyd 356



Design discharge - 3,100 second-feet

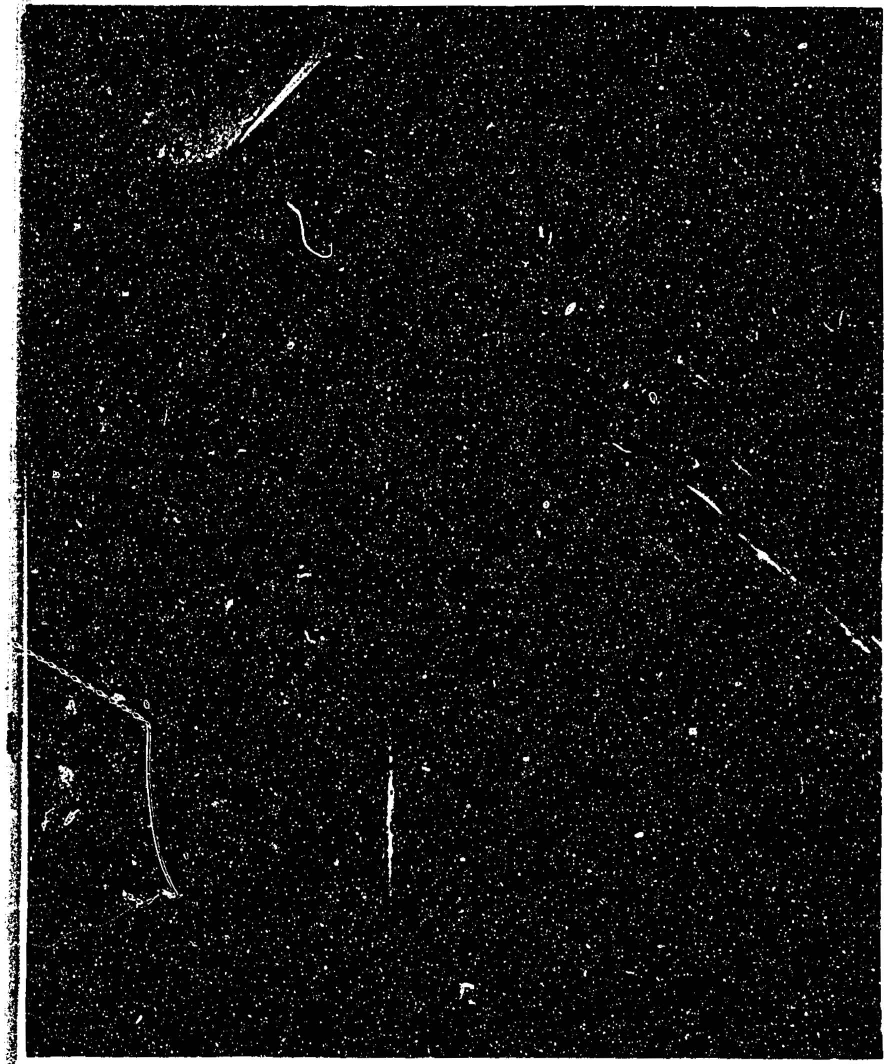


4,000 second-feet

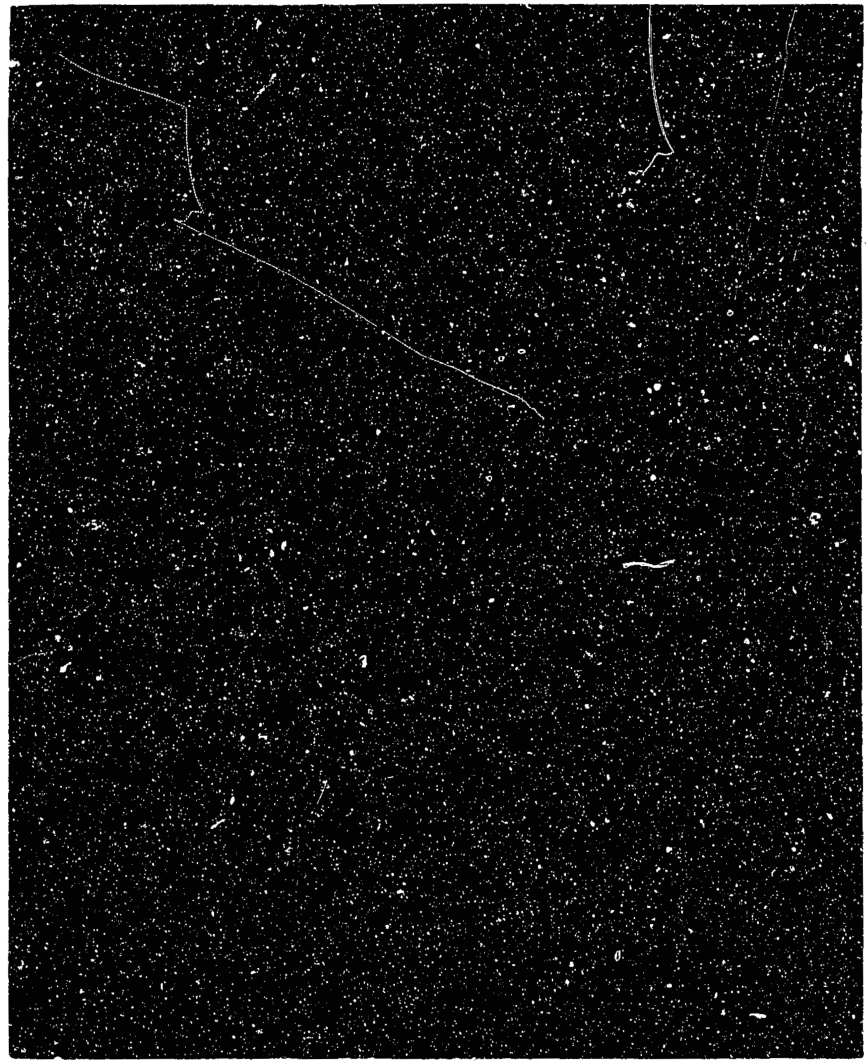
WILLOW CREEK DAM AUXILIARY SPILLWAY
Flow Currents In The Spillway Approach
1:15 Scale Model

Sheet 1 of 2

Figure 24
Report Hyd 356



4, 500 second-feet



5. 200 second-feet

WILLOW CREEK DAM AUXILIARY SPILLWAY
Flow Currents In The Spillway Approach
1:15 Scale Model

Sheet 2 of 2

Figure 25
Report Hyd 356